REPORT RESUMES

ED 013 895

VT 001 215

THE USE OF CHEMICALS AS FERTILIZERS. AGRICULTURAL CHEMICALS TECHNOLOGY, NUMBER 1.

OHIO STATE UNIV., COLUMBUS, CENTER FOR VOC. EDUC.

PUB DATE DEC 65

EDRS PRICE MF-$0.50 HC NOT AVAILABLE FROM EDRS. 128P.

DESCRIPTORS- *TEACHING GUIDES, UNITS OF STUDY (SUBJECT FIELDS), *AGRICULTURAL EDUCATION, *AGRICULTURAL CHEMICAL OCCUPATIONS, *FERTILIZERS, POST SECONDARY EDUCATION, BIBLIOGRAPHIES,

THE PURPOSE OF THIS GUIDE IS TO ASSIST TEACHERS IN PREPARING POST-SECONDARY STUDENTS FOR AGRICULTURAL CHEMICAL OCCUPATIONS. ONE OF A SERIES OF EIGHT MODULES, IT WAS DEVELOPED BY A NATIONAL TASK FORCE ON THE BASIS OF DATA FROM STATE STUDIES. SUBJECT MATTER AREAS ARE (1) CHEMICAL NUTRITION OF PLANTS, (2) PLANT GROWTH, (3) TERMINOLOGY, INTERPRETATION, AND CALCULATION, (4) NUTRIENT CLASSIFICATION, FUNCTION, AND DEFICIENCY, (5) CHEMICAL SELECTION AND RECOMMENDATION, (6) PLANT AND SOIL DIAGNOSIS AND FIELD TRIAL ANALYSIS, (7) FERTILIZER APPLICATION AND PLACEMENT, (8) APPROVED FERTILIZER PRACTICES AND RECOMMENDATIONS, AND (9) LAWFUL AND SAFE FERTILIZER HANDLING, TRANSPORT, AND STORAGE. EACH SECTION INCLUDES SUBJECT MATTER CONTENT, TEACHING-LEARNING ACTIVITY, INSTRUCTIONAL MATERIALS, REFERENCES, AND SUGGESTIONS FOR OCCUPATIONAL EXPERIENCES. A GLOSSARY OF TERMS, A LIST OF SELECTED REFERENCES, AND A GUIDE FOR SPECIFIC DEMONSTRATIONS AND USE OF VISUAL AIDS ARE INCLUDED. THE MATERIAL IS DESIGNED FOR 24 HOURS OF CLASS INSTRUCTION, 36 HOURS OF LABORATORY EXPERIENCE, AND 80 HOURS OF OCCUPATIONAL EXPERIENCE. TEACHERS SHOULD HAVE AN AGRICULTURAL CHEMICAL BACKGROUND AND STUDENTS AN OCCUPATIONAL GOAL IN THE INDUSTRY, APTITUDE IN CHEMISTRY, AND POST-HIGH SCHOOL STATUS. THIS DOCUMENT IS AVAILABLE FOR A LIMITED PERIOD FOR $6.75 PER SET (VT 001 214 - 001 222) FROM THE CENTER FOR VOCATIONAL AND TECHNICAL EDUCATION, THE OHIO STATE UNIVERSITY, 980 KINNEAR ROAD, COLUMBUS, OHIO 43212. (JM)

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL OFFICE OF EDUCATION POSITION OR POLICY.

1215

ED013895

THE USE OF CHEMICALS AS FERTILIZERS

AGRICULTURAL CHEMICALS TECHNOLOGY
No. 1

The Center for Research and Leadership Development
in Vocational and Technical Education

The Ohio State University
980 Kinnear Road
Columbus, Ohio 43212

VT001215

The development of these materials was supported by a grant
from the
Division of Adult and Vocational Research
United States Office of Education

December, 1965

MEMORANDUM

TO: The ERIC Clearinghouse on Vocational and Technical Education
The Ohio State University
980 Kinnear Road
Columbus, Ohio 43212

FROM: (Person) James W. Hensel (Agency) The Center for Vocational and Technical Education

(Address) 980 Kinnear Road, Columbus, Ohio 43212

DATE: August 7, 1967

RE: (Author, Title, Publisher, Date) Module No. 1. "The Use of Chemicals as Fertilizers," The Center for Vocational and Technical Education, December, 1965.

Supplementary Information on Instructional Material

Provide information below which is not included in the publication. Mark N/A in each blank for which information is not available or not applicable. Mark P when information is included in the publication. See reverse side for further instructions.

(1) Source of Available Copies:
Agency The Center for Vocational and Technical Education
Address 980 Kinnear Road, Columbus, Ohio 43212
Limitation on Available Copies No Limit Price/Unit $6.75/set
(quantity prices)

(2) Means Used to Develop Material:
Development Group National Task Force
Level of Group National
Method of Design, Testing, and Trial Part of a funded project of the USOE, OE-5-85-009; materials based on research from state studies; see preface materials in the course outline.

(3) Utilization of Material:
Appropriate School Setting Post High School
Type of Program Intensive, full-time, two-year, technician program
Occupational Focus Goal in the Agricultural Chemicals Industry
Geographic Adaptability Nationwide
Uses of Material Instructor course planning
Users of Material Teachers

(4) Requirements for Using Material:
Teacher Competency Background in agricultural chemicals
Student Selection Criteria Post high school level, aptitude in chemistry, high school prerequisite, goal in the agricultural chemicals industry.
Time Allotment Estimated time listed in module. (P)

Supplemental Media --
Necessary x) (Check Which)
Desirable ____)

Describe Suggested references given in module. (P)

Source (agency)
(address)

This publication is a portion of the course material written in Agricultural Chemicals Technology. To be understood fully, the complete set of materials should be considered in context. It is recommended that the following order be observed for a logical teaching sequence:

#1 - The Use of Chemicals as Fertilizers

#2 - The Use of Chemicals as Insecticides - Plants

#3 - The Use of Chemicals as Soil Additives

#4 - The Use of Chemicals as Fungicides, Bactericides and Nematocides

#5 - The Use of Chemicals to Control Field Rodents and Other Predators

#6 - The Use of Chemicals as Herbicides

#7 - The Use of Chemicals in the Field of Farm Animal Health (Nutrition, Entomology, Pathology)

#8 - The Use of Chemicals as Plant Regulators

TABLE OF CONTENTS

Suggestions for Introducing the Course 1

Competencies to be Developed

I. To develop an interest in, and an appreciation and understanding of, man's use of chemicals to attempt to satisfy the nutritional needs of plants for normal growth and development. 5

II. To understand the plant growth factors and particularly plant - soil - water and nutrients sources and relationships. 20

III. To develop the ability to use important terms, nomenclature, definitions, tables, charts and guides which are common to the field and also to develop the ability to perform important computations, conversions, calculations, and measurements which are used by technicians in the field of chemical fertilizers. . 31

IV. To learn how nutrients are classified into groups according to use or function of the element, to learn the functions of the elements in the plant growth process, and learn to recognize deficiencies of excesses of nutrients in plants. 41

V. To enable the technician to properly select and recommend various fertilizer chemicals to the customer. 52

VI. To learn the place and value of various diagnostic tests in measuring nutrient content of plants and fertility levels of soils. To understand how these tests serve as another "tool" to help the technician make recommendations to his customers. To enable the student to set up and analyze field trials and exploratory plots. 68

VII. To gain a knowledge and understanding of the principles, concepts, and practices underlying the application and placement of fertilizers. To recognize that proper timing and placement of fertilizers is as important as what is used and how much fertilizer is used. . . . 89

VIII. To gain an understanding and knowledge of approved practices and recommendations in using chemical fertilizers in a specific area. To develop skills and abilities needed to implement the practices and recommendations to satisfy the nutritional needs of the crops and to gain an awareness of the importance of knowing where and how to seek information for changing conditions. 97

IX. To acquire knowledge and skills to handle, transport and store chemical fertilizers lawfully and safely. To acquire ability to properly calibrate basic fertilizer equipment. 104

X. Glossary of Some Common Agricultural Chemical Terms, Selected References, and a Guide for Specific Demonstrations and Use of Visual Aids. 110

THE USE OF CHEMICALS AS FERTILIZERS

Major Teaching Objective

To develop personal qualities and effective abilities needed for entry and advancement by technicians in chemical fertilizer occupations.

Subsidiary Objectives

1. To develop an interest in and an appreciation of the role which chemicals have in the production of plants and in the ability of man to satisfy nutritional needs of plants by the supplemental use of chemicals.
2. To gain an understanding of the principles of plant nutrition, crop growth and production, soil science, and the use of fertilizers; to gain knowledge and skill essential to the qualification of technicians for work in the areas of soil fertilization and plant nutrition.

Suggested Time Allotment

At School		
Class Instruction	24 hours	
Laboratory Experience	36 hours	
Total at School		60 hours
Occupational Experience (Over a two-year period)		80 hours
Total for Course		140 hours

Suggestions for Introducing the Course

The general field of plant nutrition and soil fertility constitutes one of the major components of the agricultural chemicals complex. A person preparing for employment within this field at the technical level needs to have practical and theoretical knowledge concerning a wide spectrum of plant production in order to be qualified as a technician.

Competition is exceedingly keen in the production and sale of chemical fertilizers. Only those who will qualify themselves technically and become highly competent can expect to succeed in most fertilizer businesses. Rewards will be proportional to the efforts expended and the knowledge the technician possesses.

The following suggestions may be helpful in arousing a high level of interest in the student at the start of this unit.

1. Show by pot and flat demonstrations, using sterile sand and indicator plants, the effects of deficiencies and excesses of various nutrients. (Make no attempt to study fertilizer elements and plant nutrient requirements in detail at this point.)

2. Determine, with the students, the amounts of different plant nutrients utilized annually by a few representative crops which are grown locally. Calculate the value of each according to the current price of fertilizers.

3. Study the amounts and values of various fertilizers used annually at the local, state, and national levels.

4. Obtain data from local farmers, county agents, farm advisors, and representatives of industry and business regarding various applications and responses of fertilizers on different soils and crops. Determine the value which results from such applications by comparing yields with check plot results or local norms.

5. With the students, prepare a list of the names of business firms in your community who engage in the fertilizer business. Develop a list of the functions performed by these firms. Some of these functions are:

   a. To sell chemical fertilizers

   b. To compound and mix fertilizers

   c. To sell pesticides

   d. To test soils for levels of fertility

   e. To test plant tissue for nutrient deficiency

   f. To advise others regarding the use of fertilizers and pesticides

   g. To apply fertilizers and pesticides

6. Have the students determine the various kinds and combinations of fertilizers which are available from local firms. Stress the wide range of chemicals available for both general and specific uses. Display samples of each kind:

   a. Complete fertilizers

   b. Standard pre-mix fertilizers

   c. Supplemental fertilizers

   d. Major element fertilizers

   e. Minor element fertilizers

   f. Other--

7. Develop a list of factors with the students which tend to complicate the task of supplementally satisfying the nutritional needs of plants (do not go into detail at this point):

   a. Varying nutrient requirements of plants according to such variables as age, kind, growth rate, use intended for, etc.

   b. Varying composition of the soil and the different levels of soil fertility

   c. Varying amounts of soil moisture

   d. Varying temperatures, light intensities, wind, day lengths

   e. Different varieties and productive ability of varieties, density of stand

   f. Other--

8. From information obtained from workers in industry, business, public service, and education develop a list of the skills, abilities and understandings which agricultural chemical technicians need for employment in the fertilizer industry. The list will probably include entries for each of the following sub-headings:

   a. Man's use of chemicals to attempt to satisfy the nutritional needs of plants

   b. Federal, state, and local laws, controls, and regulations which pertain to the sale and use of fertilizers

   c. The recognition and identification of symptoms of nutritional stress in plants and the determination of levels of soil fertility

d. Various chemical resources available for use to satisfy the nutritional needs of plants

e. The principles of plant nutrition, chemistry, and soil science upon which fertilization program is based

f. Skills, abilities, and understandings needed to plan a fertilization program

g. Important terms, nomenclature, definitions, tables, charts, and guides commonly used and important computations, calculations, conversions, and measurements performed

h. The handling and applying of fertilizers in a proper manner, using approved methods and equipment

Competencies to be Developed

I. To develop an interest in, and an apprecation and understanding of, man's use of chemicals to attempt to satisfy the nutritional needs of plants for normal growth and development.

Teacher Preparation

Subject Matter Content

The first unit of this course is divided into three main sections. Part one - chemistry and fertilizers; part two - history of fertilizers and development of fertilizer science; part three - present use and need for fertilizers.

The first part may be used to introduce the science of chemistry and its implications to agriculture. If the students have had a preparatory course in chemistry the instructor should quickly cover the material and stress only those sections that are vital to fertilizer knowledge and understanding.

Students that have not had chemistry should know and understand the terms and material covered. The student should appreciate that all matter is formed in a systematic, orderly way. He should also understand how elements go together to make matter. He should know that materials such as proteins in plants utilize an element like nitrogen regardless of the source of the nitrogen; organic or inorganic.

Review basic chemistry. Use examples and simple chemical reactions the student can understand and see.

This material is vital to the complete appreciation and understanding of soil, plant, fertilizer relationships.

The second portion is designed to develop in the student an appreciation of the science of fertilizers and that it is a relatively new science. The student will be able to see and understand how many superstitions originated. The student should also treasure the fact that the knowledge we now possess has come about through years of frustration and painstaking research on the part of others.

There is much still to be learned; the student should be challenged to seek new and better ways to meet our crop needs.

The third portion of the unit shows how important fertilizers are to our nation's agriculture. High yields, economical returns, and low-cost food are dependent on fertilizers and their proper use.

Part I - Chemistry and Fertilizers

A. Chemistry and the farmer

1. Why should we know something about chemistry?

a. Emphasize that fertilizers are chemicals

b. Important to better appreciate what we are doing and know how chemicals combine into other compounds.

c. The technician should be able to overcome farmer objections to chemicals that are based on false ideas or superstition

d. Intelligent, logical presentation of facts will sell a product

e. Remember - opinions are cheap and facts are hard to come by. One good fact can refute an argument

B. Chemical terms

A. Elements

1. Units of building materials from which all else is made

a. They cannot be separated into other substances

2. All matter above, on, and inside the earth is made up of only 103 known elements

a. Includes such elements as Californium, Mendelevium, Gold, Silver, Copper, Lead, etc.

b. Two are liquids, bromine and mercury; 11 gases; remainder solids

3. Human body made up of 13 measurable elements (iodine - .00004%)

O	-	75%
H	-	10%
C	-	18%
Na	-	3%
Ca	-	1.5%
P	-	1.0%

Mere traces of others make tremendous differences, however; flourine, iodine, etc.

4. Only 13 elements make up 99.7% of earth's crust (10 mi. deep)

    a. Four elements make up 90%. Oxygen 50% - Silicon 25% - Aluminum 7 1/2% - Iron 4 1/2%

5. Sixteen known essential elements required for plant growth

    a. C,H,O, - N,P,K, - Ca, Mg, S - B, Cl, Fe, Cu, Mn, Zn 90-95% of plant wt. made up of C,H,O

    b. Many other elements present

    c. (Details will be covered later)

C. Atom--Word means "not cuttable" in Greek

1. If you took a piece of pure gold and broke it down into the smallest possible particles (without losing its identity) you would have atoms. (Like cells in a piece of tissue.)

    a. Take all the atoms in a glass of water and let it mix with all the other water on earth for a few million years. Now draw a glass from the top and how many molecules from the original glass would you find?

    2000 - for there are that many times more molecules in a glass than there are glasses of water on the whole earth. There are 33 billion molecules of water in a single drop of water.

2. The atoms have never been seen; they have weights - electrical charges and many other characteristics.

    a. Atoms have electrical charges called protons, neutrons, and electrons

    b. Protons have positive charge and are found in nucleus

    c. Neutrons have no charge and are also in nucleus (Not in nucleus of H atom, however)

    d. Electrons are negative and surround nucleus

        1. Equal numbers of electrons and protons make a neutral whole

        2. More protons than electrons give atom a positive charge and vice versa

e. These electrical charges are extremely important in determining how elements react and affect availability of the elements in the soil

f. The Hydrogen Atom

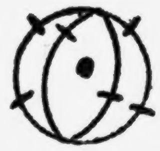
  1. Atomic No. of H is 1

    a. Nucleus made up of a unit of positive charge

    b. Surrounded by revolving electron - (Negative charge)

    c. Loss of this electron under certain conditions leads to the formation of the Hydrogen Ion represented by symbol H^+

  2. Popular concept of atom as shown



    a. If H atom could be blown up to 22 story building covering a full city block, the nucleus would be the size of a marble

    b. Even so, nucleus contains 99% of the mass

  3. The degree of readiness with which an atom loses its outer electrons reflects on how chemically active an element is

    a. Some elements like lithium, Ca and Al readily lose electrons and become ions Li^+ Ca^{++}, AL^{+++}

    b. Others do not and are inert-Helium and Neon, Gas, Gold, Platinum, etc.

    c. These positively charged atoms are cations

  4. Some elements (the non-metals) add electrons

    a. Chlorine, Florine become Cl^- and F^-

    b. They are anions and are negatively charged

  5. Emphasize how cations are attracted to and held by negatively charged clay and humus materials in the soil

     Briefly discuss how this affects selection, applications, and timing of fertilizer materials

D. Compounds

1. Substances made up of two or more elements are compounds

   a. May be gas, liquid, or solid

   b. Compounds usually look and act entirely different than their parent elements

      1. H and O inflammable ⟶ water

      2. C, H, and O tasteless ⟶ sugar

      3. Na and Cl poison ⟶ salt

2. Ionic Compounds -- Atoms or groups of atoms that possess a positive or negative charge are ions [cations - positively charged anions -- negatively charged]

   a. Substances composed of ions are called ionic compounds

   b. Natural attraction between two ions with different charges

      Na (positive) comes in contact with Cl (negative) and forms salt

   c. When one ion has a double charge it combines with two ions of the opposite charge

      Mg^{+} + attracts F^{-} (fluorine)
      $Mg \quad 2F \rightarrow Mg\,F_2$

      $Al^{+++} \; + 3F \rightarrow AL\,F_3$

   d. The number of electrons gained or lost by an element is called its Valence

3. Other compounds are made up by sharing electron pairs = (they don't give up electrons) essentially the same results occur except the bond between atoms is in pairs

4. Combinations of these two forms also occur

E. Molecules

1. The combination of atoms that make up the smallest possible unit of a compound is a molecule

a. May be different atoms or similar

1. Found as O_2, N_2

2. Na Cl -

2. Two atoms of hydrogen combine with one atom of oxygen to form a molecule of water

a. Millions of these molecules make up a drop of the water

3. Some elements are found as a group of 2 or more atoms which form a molecule

F. Symbols

1. The elements all have abbreviated forms that make up the symbols

a. These abbreviations are similar to the ones we use for our states

2. Most symbols are similar to the first letter or letters of the element. C, H, O, N, P, I, Cl, Ca

3. Others have been derived from Latin and Greek sources of the element. Fe, K, Mg, Cu

4. Symbols we need to know and remember (16 elements needed by plants)

1. C
2. H
3. O
4. P
5. K
6. N
7. S
8. Ca
9. Fe
10. Mg
11. B
12. Cu
13. Mn
14. Mo
15. Zn
16. Cl

Na + I, may be helpful to plants but are not accepted as essential

G. Equations

1. Symbols and formulas can show chemical reactions and the formation of compounds

2. $H_2O \longrightarrow 2H + O$

Decomposition of molecule of water yields 2 atoms of H and one of O

3. Photosynthesis

   $6\ H_2O + 6_{CO}2$ and Energy from sunlight $\rightarrow C6H_{12}0_6 + 60_2$

4. N and H both found in air as a mixture. They are made into a compound through use of electricity and catylist to form NH_3

   Ammonia and water forms ammonium hydroxide

   $NH_3 + H_2O \longrightarrow NH_4OH$

Part II - History

A. History of Soil Fertility

Point out that 150 years ago even the most brilliant of men did not know what the student of today has now learned. Imagine the questions the great thinkers must have had about the why, where, and how of plant growth.

1. First use of manure to restore soil fertility is lost in antiquity

2. Homer alluded to the systematic use of manure in his poem The Odyssey. This dates back to 700 B.C. or possibly even earlier

3. Other writers before the time of Christ referred to the maintenance and improvement of land thru the use of manure

4. Other writers, Xenophon (around 400 B.C.) and Cato (234-149 B.C.), wrote about the values of green manures and particularly of the value of legumes

5. Writers of the Greek and Roman era discussed other practices such as the use of marl and other liming materials, mixing soil from other areas with one's crop land, the value of ashes and even the use of certain salts. Indeed most of our "modern" ideas have roots two to three thousand years old

6. The great thinkers of Greece and their Roman counterparts did not understand the "why" of their recommendations and during the dark ages much of their findings were lost

7. During the seventeenth and eighteenth century a number of great men began to delve into the mysteries of plant growth and soil fertility

a. Van Helmont (1577-1644) placed 200 pounds of soil in an earthen container. He carefully weighed a willow shoot and protected the container from contamination. After five years of adding only distilled or rain water, he carefully weighed the willow and found a gain of over 164#. He also weighed the soil and found it only weighed approximately 2 oz. less than it's original weight. Naturally he concluded all plant growth came from water.

b. Others checked van Helmont's work and proved plants grew better with dirty water than they did with distilled water. Still others, Glauber (1604-68) found salts such as saltpeter (KNO_3) made plants grow better.

c. With trial and error, painstaking research, improved and expanded scientific knowledge and research techniques man slowly added to his knowledge of soil fertility and plant growth.

Science gradually acknowledged that there was no one substance responsible for plant growth. Soil, water, air, salts, humus, oil, and other substances were thought to be essential.

8. Justus von Liebig (1803-1873) is considered to be the "father of agricultural chemistry" because of his experiments and conclusions carried out only slightly over 100 years ago. Among other things he stated that:

a. Most of the C in plants came from the CO_2 of the atmosphere.

b. Water was the main source of H and O.

c. The growth of plants was proportional to the amount of mineral substances available in the soil or fertilizer.

Von Liebig's "Law of the Minimum" still stands. In effect his law states that plant growth is limited by that element found in the smallest required amount, all other elements being equal. We often refer to the weakest link in a chain.

9. Refined research techniques, new knowledge and thorough field and plot testing have changed many of the old ideas. Most of our fertilizer practices of today date back less than a person's lifetime even though there may have been a germ of an idea 3,000 years ago.

10. New materials, sophisticated application methods, new cultural practices, new crops and varieties of crops all point toward a continued changing pattern of fertilizer use and practices.

    Will you be prepared to change with them and keep up with the technological advances?

Part III - Use and Need of Fertilizers at Present

A. Use of Fertilizers

1. In 1964 farmers in the United States spent 1.7 billion dollars for fertilizer and applied more pounds of plant food than ever before.

   As potential fertilizer salesmen, you will be happy to know, and should tell all customers, that fertilizer is today's best buy.

2. It has been estimated that 20% of all farm production in the United States is due to fertilizers. In some places in the south, they estimate that 75% of the production is due to fertilizers.

   a. Rundown, unproductive farms have been restored through good management practices and fertilizer use. As a result, land values as well as crop yields have gone up.

3. Farmers are caught in a tight cost-price squeeze. Fertilizers are one of the best ways to reduce the cost per unit of production.

   In this example, all costs are fixed except the amount of fertilizer applied. These are realistic figures taken from field trials with corn in Ohio. The teacher could develop more appropriate examples from his own state to make the point seem close to home. The fixed costs of growing an acre of corn were:

Land	$ 9.50
Machinery	12.00
Labor	14.00
Supplies (seed, weed spray, etc.)	8.00
Miscellaneous costs	1.50
Total costs, except fertilizer	$45.00 an acre

Three levels of fertilizer were applied with the following costs and results. Cost of fertilizer is on "field applied basis."

Level of application per acre	Cost of fertilizer	Bushels of corn per acre
Low - 100 lbs.	$ 4.00	45.0
Average - 228 lbs.	9.12	51.3
Recommended - 700 lbs.	28.00	76.5

The economic results can be seen in the following tables. Note that at $1.00 per bushel, fertilizer levels below the recommended level would result in a net loss.

Level of application per acre	Total costs, fixed plus fertilizer	Value of corn at		
		$1.00	$1.15	$1.30
Low	$49.00	$45.00	$51.75	$58.50
Average	54.12	51.30	59.00	66.69
Recommended	73.00	76.50	87.98	99.45

Level of application per acre	*Profit or loss per acre		
	$1.00	$1.15	$1.30
Low	-$4.00	$2.75	$9.50
Average	- 2.82	4.88	12.57
Recommended	3.50	14.98	26.45

Three factors have a relationship to the profit derived from growing a crop:

1. The total costs of production
2. The level of production (bushels of corn)
3. The market value of the product (corn). Quality as well as current prices affect value received

*In many cases extra growth and yields may result in slightly higher costs in weeding, extra irrigation and harvest. These costs vary by areas and crops.

B. Need for Fertilizers

Peoples of ancient civilizations knew that continued cropping of the soil resulted in lower yields and in their words "sterile" soil.

Columella recommended to his fellow Romans that "the leaner and more pendent places in the pasture be dunged." Both the Greeks and Romans knew the value of manure in restoring growth and production in depleted farm lands.

Early Americans, however, found that it was cheaper to move on to new land than to restore fertility on old farms. We have few areas in which to move today, however, so once again we think of the soil as a bank.

One may inherit a sum of money and make periodic withdrawals. The account must be replenished more and more frequently as one gets a smaller balance. The soil we started farming is like that bank account and as we farm soils for long periods the balance sheet shows a smaller and smaller reserve. Our withdrawals are also getting larger and larger as we improve our crops and other management practices and increase yields.

SUGGESTED TEACHING-LEARNING ACTIVITIES

1. Assign several students to be responsible for contacting the State Department of Agriculture or State Bureau of Chemistry to determine usage of chemical fertilizers in your state.

2. Other students could gather information on fertilizer trials to obtain information on yield increases due to fertilizers.

3. Convert above yield increases into cost of production studies for major crops.

4. Visit any fertilizer demonstration plots that may have been set up in your area.

5. Start some simple pot tests with fertilized and unfertilized soil to demonstrate crop response.

SUGGESTED INSTRUCTIONAL MATERIALS AND REFERENCES

Instructional Materials:

1. Work up graphs showing response of local crops to fertilizer treatment.

2. Have graph that shows yield increases for a major crop in your area for the last fifteen - twenty (15-20) years. Discuss reasons for increase.

References:

Tisdale, S. L. and Nelson, W. L., Soil Fertility and Fertilizers; New York: The Macmillan Co.

The Fertilizer Handbook; National Plant Food Institute, 1700 K Street, N.W., Washington, D.C.

Western Fertilizer Handbook; California Fertilizer Association, 719 K Street, Sacramento, California.

McVicker, M. H., Using Commercial Fertilizers, Danville, Illinois, Interstate Printers and Publishers.

Black, C. A., Soil - Plant Relationships; New York: John Wiley and Sons.

Donahue, Roy P., Soils, Englewood Cliffs, New Jersey, Prentice-Hall, Inc.

Fertilizer Facts, Industrial and Biochemicals Department, E. I. duPont de Nemours and Co., Wilmington 98, Delaware.

SUGGESTED OCCUPATIONAL EXPERIENCES

Have the students develop and set up a fertilizer test demonstration to compare organic and chemical fertilizers. Since the students have not yet learned how to calculate amount of materials needed for the plot the instructor should provide the answers at this time.

II. To understand the plant growth factors and particularly plant - soil - water and nutrients sources and relationships.

Teacher Preparation

Subject Matter Content

The students should be cognizant of the many factors affecting plant growth, fertilizer use, and response. This portion of the course should cover a review of basic plant science, soils, and plant growth factors. The material will serve as an introduction to sources of applied nutrients and why such applications are changing.

A. Plant Processes Review

1. Photosynthesis - it should be pointed out that the simple formula used to demonstrate photosynthesis is not entirely accurate. We now know that substances other than sugar are produced in the process.
2. Transpiration - briefly discuss
3. Respiration - briefly discuss
4. Osmosis - briefly discuss
5. Plasmolysis - indicate how fertilizer salts can inhibit seed germination by increasing the salinity concentration in the soil solution. Discuss how fertilizers can "burn" plants by being placed too close to roots, by using concentrated sprays or by excessive application. (Some excellent demonstrations can vividly demonstrate several important points.)
6. Translocation - briefly discuss
7. Assimilation - discuss the use of radioactive tracers used to pinpoint nutrient movement and assimilation in plants.

B. Soil Review With Emphasis on Fertilizer and Nutrient Relationships

1. Soil has three properties:

    a. Physical - texture, structure - color

    b. Chemical

    c. Biological

    All three affect fertilizers and plant nutrition.

2. Texture

   a. Sand, silt, clay

      (1) Clay fraction is the "active" part of the soil

      (2) Clay is primary source of nutrients taken up by plants and for nutrients that go into solution

      (3) Clay has a negative charge and attracts positively charged nutrient such as NH_4^+, CA^{++}, Mg^{++}, K^+. Negatively charged ions such as NO_3^- are repelled and readily move with the soil water. Such ions may leach out of the root zone or move with water to the soil surface through capillary rise

      (4) Humus acts much the same as clay in its effects on nutrients

      (5) The latticed clay structure may tie up many nutrient ions. N, and particularly P and K are all tied up by clay particles and may be made unavailable for plant use

3. Soil structure

   a. Deflocculated (puddled or dispersed) soils can inhibit water movement and/or root growth

   b. Soil-pans that inhibit water movement may cause perched water tables that can drown the plant roots and also cause loss of N to the air

   c. Roots will not grow in dry soils and, therefore, the area from which they may "feed" is reduced and the plant yield may be reduced

4. Biological property of soil

   a. Organisms are found in soil in fantastic quantities. For example, a gram of soil may contain several billion bacterial cells plus large numbers of algae, fungi, and protozoa.

   b. Factors affecting biological organisms in soil

      (1) Temperature - little conversion of organic matter or NH_4^+ to NO_3^- during periods when temperature is under 40° F.

      (2) Moisture

      (3) Air - anaerobic bacteria will reduce NO_3 to N_2 which is lost to plant use

(4) N content of soil or organic matter

(a) A wide C:N ratio in stubble such as corn stover, straw and in many mature plants results in a tie-up of soil N. Plants such as those mentioned have a ratio of about 60:1

(b) A favorable C:N ratio is approximately 15:1 and has approximately 2.5% N in the residue

(c) When plowing down stubble and other low N crops add N to hasten breakdown and prevent N tie-up. 20# to 30# of N per ton of straw will generally give adequate N

(5) Organic matter content of soils

(a) Soils high in O.M. generally have a more active biological fraction in the soil

(b) When adding O.M. to the soil in the form of cover or green manure crops work the crop down before it gets mature. This results in a favorable C:N ratio and prevents N tie-up and subsequent deficiency to the crop

c. Symbiotic and non-symbiotic organisms

(1) Most notable of the symbiotic bacteria belong to the genus Rhizobumi. (Nodules of legumes.) Because of the ability of these bacteria to get N from air one may add over 100# of N per ac. by growing legumes and plowing them under. This may be an expensive way to add N, however.

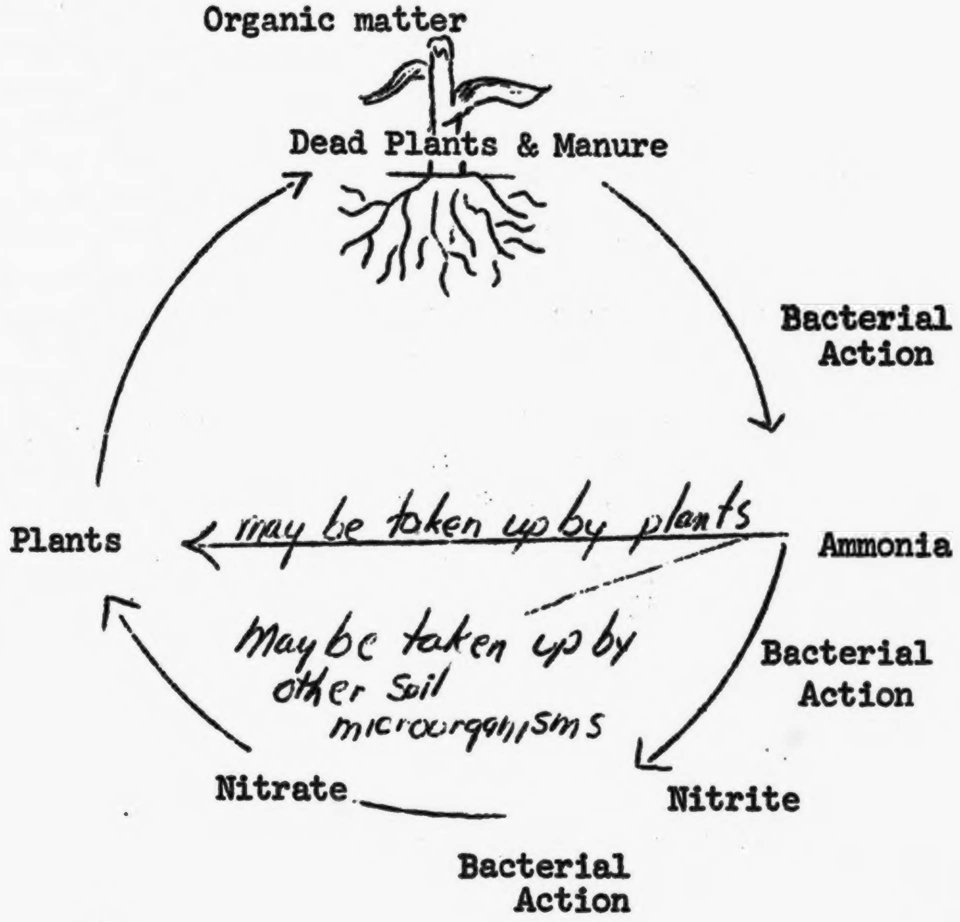
(2) Some non-symbiotic bacteria are capable of N fixation. Azotobacter and Clostridium. Amount added to soil is small, however.

d. Biological organisms and mineralization of organic matter

(1) Almost all soil N comes from O.M. or applied fertilizers

(2) N in organic matter must be released from the protein in the organic matter to forms available to plant

(3) This is done through the action of microorganisms--N cycle.


Organic matter
Dead Plants & Manure
Bacterial Action
Ammonia
may be taken up by plants
Plants
May be taken up by other Soil microorganisms
Bacterial Action
Nitrite
Nitrate
Bacterial Action

        - (4) Discuss N cycle - influence of temperature, moisture, etc.
        - (5) Important to realize that other soil organisms will also use the ammonia and nitrate N in the soil

5. Chemical properties of soil

    - a. Of the many chemical properties of soils one of the most important is pH
    - b. Acid soils
        - (1) Below 7.0
        - (2) Most micro nutrients are more available at lower pH ranges. Mo excepted
        - (3) Acidity affects microbial activity of soil. N may not be converted from NH_4 to NO_3 form due to inhibiting bacterial action
        - (4) P is tied up in insoluble compounds in acid soil
    - c. Neutral soils
        - (1) pH 7.0 neutral
        - (2) pH of approximately 6.7 to 7.2 are agriculturally neutral
        - (3) pH range generally most favorable to plants
    - d. Basic soils
        - (1) pH above 7.0
        - (2) Saline soils--generally good texture, high in salts, pH usually below 8.5, often called white alkali
        - (3) Sodic or black alkali soils--pH usually above 8.5, deflocculated soil, 15% or more exchangeable Na
        - (4) Instructors should discuss local problems and ramifications of fertilizers and soil conditions

C. Nutrient Uptake by Plants

1. Plants vary in their ability to take up nutrients from the soil
    - a. Depends on exchange capacity of roots
    - b. Requires energy on part of the plant
    - c. Needs metabolic activity to take place
    - d. Proceeds independently of water uptake
2. Nutrient movement from clay to root
    - a. Solution theory
        - -- Root gives off CO_2
        - -- CO_2 dissolves in water forming H^+ and HCO_3 (bicarbonate ion)
        - -- H^+ replaces K^+ on clay
        - -- Then K^+ moves to surface of root
    - b. Contact theory
        - -- Swarm of positive ions around clay particles
        - -- Part of + ions held both tightly and loosely
        - -- Root has negative charges and attracts + ions held loosely by clay
        - -- Cation Exchange
        - -- Two swarms of bees
        - -- H^+ still comes out of root due to CO_2
    - c. Probably both theories are true
        - -- Solution theory probably predominates in sandy soil where it is wet
        - -- Contact theory in clay soil and dry soil
3. Movement from root surface into cells
    - a. Osmosis
        - -- Water movement from dilute to concentrated solution
        - -- Water molecules small and due to constant movement they go through openings
        - -- Large sugar molecules block openings so more molecules move into than out of concentrated solutions
        - -- As more and more molecules move in pressure increases in sugar solution so finally as many water molecules move out as move in

- -- Like barbed wire fence holds cows in but sheep go both directions
- -- At high temperature activity is increased
- -- On hot day, cold irrigation water slows down the intake of molecules and transpiration may exceed uptake and plant wilts

b. Formerly thought nutrient uptake was in solutions only

c. Then thought ions passed through by process similar to osmosis. Diffusion

- -- Now know it's not so because if plant is moved from concentrated solution into distilled water, it doesn't give up K^+ ions to water

- -- They also put plants into radioactive solution and plants pick up tracer elements. They do not give up these elements to solutions void of the element

- -- Know plants can select nutrients and also that the uptake of minerals is a one-way affair

d. The cation of minerals is attracted to root surface and then hooks up to unknown carrier that pulls it through cell wall

- -- Cell membrane acts as hostess and bouncer encourages entry of some ions--and rejects others

- -- Hoagland took seedlings and put them in two vials filled with solutions K^+

- -- Bubbled N_2 through one to expel O_2 and bubbled air through one to add O_2

- -- Result
  Solution with air expelled resulted in no uptake of K. Also found that low temperature (refrigerated vials) had no uptake

- -- Conclusions - uptake of nutrients is an active process requiring energy, thus O_2 and temperature influence uptake

- -- Molecular boats is name given to agent carrying ions through membrane of cell

- -- Carrier works only in one direction

  - -- Ion does cross as such but goes into molecular combination with carrier
  - -- This chemical reaction explains why ions of similar nature are taken in and others are not
  - -- Strontium 90 and Ca
  - -- K and Rubidium

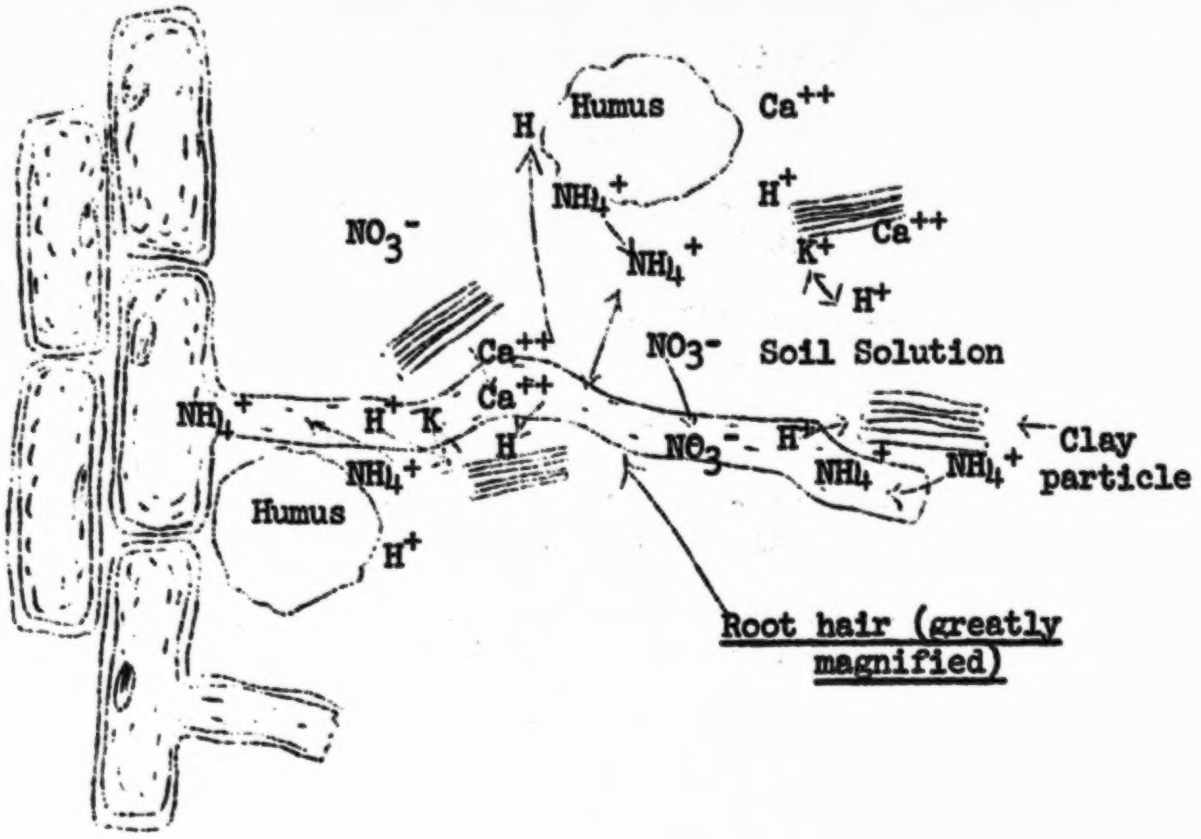
e. Some say there are only two major processes to incorporate outside elements into cells

  - -- Photosynthesis
  - -- Carriers of elements

f. Management practices that encourage uptake

  - -- Only young roots take up nutrients so growth must be kept active
  - -- Need soil of good tilth and moisture to stimulate root growth and development
  - -- Temperature affects root growth
  - -- Need rich soil and a balance of nutrients available so roots can grow
  - -- Adequate aeriation -- uptake of nutrients requires energy so O_2 is needed

Portion of Root Showing Cells Greatly Enlarged


H
Humus
Ca^{++}
NH_4^+
H^+
NO_3^-
NH_4^+
K^+
Ca^{++}
H^+
Ca^{++}
NO_3^-
Soil Solution
NH_4^+
H^+
K
Ca^{++}
H
Clay particle
NH_4^+
NO_3^-
H^+
NH_4^+
NH_4^+
Humus
H^+
Root hair (greatly magnified)

Note that calcium, ammonium, potassium and other cations are found both in the soil solution and adsorbed to clay and humus particles. Hydrogen ions and other cations are exchanged on the clay and humus for cations taken up by the plant or for those that go into solution.

Anions such as nitrates are not adsorbed by the clay particles. These ions are found in solution and move from the solution to the root surface.

SUGGESTED TEACHING-LEARNING ACTIVITIES

1. Plant barley, oat, corn, or wheat seeds in the same soil that has had the pH range in different pots artificially changed from low to medium to high.

2. Deflocculate a heavy soil by packing it into a pot while wet. Fill another pot with the same soil and plant seeds in both.

3. Transplant plant seedings into two pots. Provide drainage in one and no drainage in the other. Observe effects of excess soil moisture and poor drainage.

4. Take a field lab through the crop growing area. Observe the "trouble" spots and discuss the possible reasons for the trouble. Try and find places with the following problems:

   a. Poor drainage

   b. Excess moisture

   c. Nematode damage

   d. Insect damage

   e. Acid, alkali, or saline spots

   f. Nutrient deficiency

5. Plant corn in two pots - one filled with sand and the other with a heavy soil. Fertilize both and water liberally. Observe which first shows deficiency symptoms. Discuss reasons.

SUGGESTED INSTRUCTIONAL MATERIALS AND REFERENCES

Instructional Materials:

1. National Plant Food Institute slides: "Soils, Plant Nutrition and Fertilizers."

2. National Plant Food Institute poster, "How Soil pH Affects Plant Food Availability."

References:

Tisdale, S. L. and Nelson, W. L., Soil Fertility and Fertilizers; New York: The Macmillan Co.

The Fertilizer Handbook. National Plant Food Institute, 1700 K Street, N.W., Washington, D.C.

Western Fertilizer Handbook. California Fertilizer Association, 719 K Street, Sacramento, California.

Black, C. A., Soil-Plant Relationships, New York: John Wiley and Sons.

Bear, Firman E., Soils and Fertilizers, New York: John Wiley and Sons.

Spurway, C. H., Soil Fertility Diagnosis and Control. Published by the author, East Lansing, Michigan.

Buckman, Harry O. and Brady, Nyle C., The Nature and Properties of Soils, New York: The Macmillan Co.

Donahue, Roy P., Soils, Englewood Cliffs, New Jersey. Prentice-Hall, Inc.

SUGGESTED OCCUPATIONAL EXPERIENCES

If it's possible, make arrangements for the students to spend time riding with one of the fertilizer field men or Extension Agents in your area. It may be possible to assign students to one or more such trips during the semester. A report should be written and presented to the class following each such experience.

III. To develop the ability to use important terms, nomenclature, definitions, tables, charts, and guides which are common to the field and also to develop the ability to perform important computations, conversions, calculations, and measurements which are used by technicians in the field of chemical fertilizers.

Teacher Preparation

Subject Matter Content

The unit should enable the student to intelligently converse with people in the industry. Stress the need to properly use fertilizer terminology on field labs and when dealing with customers.

Technicians must be able to compute quantities and costs of fertilizers used by farmers.

A. Terms

1. Fertilizer - any substance added to the soil to supply elements required in the nutrition of plants.
2. Fertilizer material - any substance which contains one or more plant-nutrient elements. Some state laws require a minimum of 5% or more nutrient content before a material may be called fertilizer.
3. Mixed fertilizers - fertilizers containing two or more fertilizer materials.
4. Complete or balanced fertilizer - fertilizer containing N, P, and K, the three main plant food elements.
   a. Stress that these materials are neither complete nor balanced.
5. Simple fertilizer - contain only single nutrient of N, P, or K.
6. Fertilizer grade or analysis - minimum guaranteed per cent of plant nutrient content of:
   a. Total nitrogen
   b. Available phosphorus as P_2O_5
   c. Water soluble potassium as K_2O

   The grade or analysis is always given in the order of N, P_2O_5, and K_2O (or NPK as the new labels show).

7. Fertilizer ratio - the relative amount of N,-P_2O_5 and K_2O in fertilizer reduced to the lowest common denominator.

   For example:

Grade	Ratio
13-39-0	1-3-0
4-16-16	1-4-4
13-13-13	1-1-1
6-18-12	1-3-2

8. Filler - material added per ton of mixed fertilizer to make up the difference in weight between the ingredients needed for a given analysis and 2,000 pounds. Filler may be inert material such as sand, clay, or limestone for neutralizing acidity, or it may be soil conditioning materials.

9. Conditioner - material added to fertilizer to prevent deliquesence, caking, dust, etc. Also added to improve spreading quality of the product.

10. Phosphate Solubility - The solubility of phosphorus compounds are measured by tests designed to approximate the amounts of phosphate which will be available to plants from phosphate fertilizer material.

    a. Water-soluble P_2O_5 - amount of a phosphate material expressed as P_2O_5 which is soluble in water under prescribed conditions.

    b. Citrate - soluble P_2O_5 - amount of a phosphate material which is soluble in neutral, normal ammonium citrate under prescribed conditions.

    c. Available P_2O_5 - the available P_2O_5 shown on a fertilizer bag represents the sum of the water-soluble P_2O_5 and the citrate-soluble P_2O_5, since both of these types of phosphate are relatively available to plants.

11. Fertilizer formula - List of kinds and amounts of nutrient materials used to make a specific fertilizer.

12. Unit - Technically denotes one per cent of a ton. Commonly used as a synonym for a lb. "40 units of N per ac means 40# of N per ac."

13. Acid forming fertilizers - Fertilizers capable of increasing acidity of soil such as:

    a. $NH_4 NO_3$

    b. $(N H_4)_2 SO_4$

    c. H_3PO_4

    d. NH_3

14. Basic residue fertilizers - Fertilizers capable of raising pH of soil such as:

    a. $Ca (NO_3)_2$

    b. $NA NO_3$

15. Soil amendments - Materials added to the soil to raise or lower pH or improve the soil condition and structure.

    Examples:

    Lime and dolomite - raise pH

    Sulfur, sulfuric acid - lowers pH

    Gypsum - helps reclaim sodic soil and may improve soil structure

16. Low analysis or ordinary grade fertilizer -- contains less than 20% total N, $P_2 0_5$ and $K_2 0$.

17. High analysis or high grade -- contains 20-30% total N, $P_2 0_5$ and $K_2 0$.

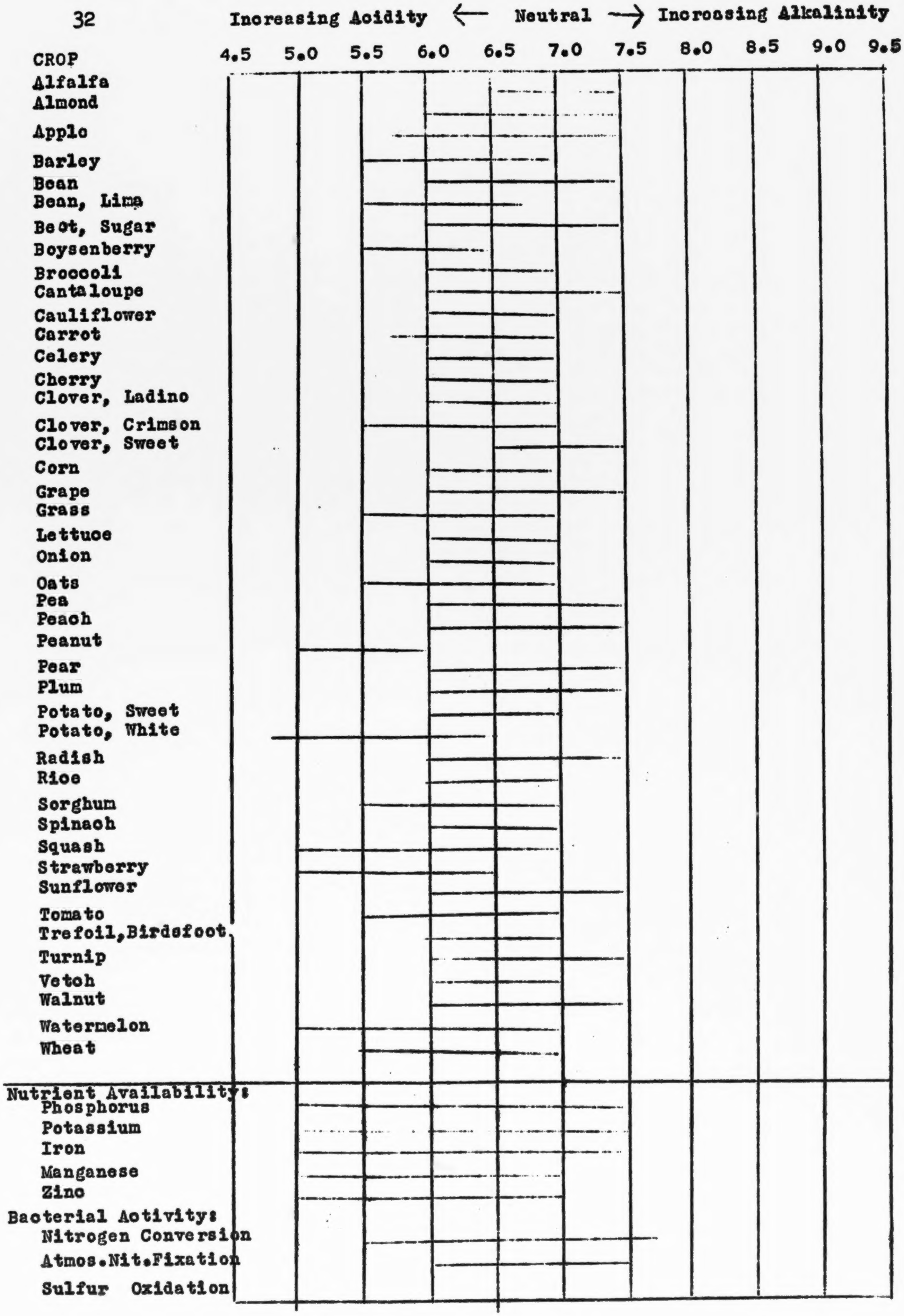
18. Concentrated fertilizer -- contains over 30% total N, $P_2 0_5$ and $K_2 0$.

19. Chlorosis - Loss of chlorophyl in plants causing the plants to turn yellowish, or pale green.

B. The technician will be called upon to interpret many tables and charts and guides. The following charts and tables should be familiar to the technician.

   1. pH range normally favorable to growth of some common crops. (See following page.)

   2. pH range at which major nutrients are most available. (See bottom part of following chart.)


Increasing Acidity ← Neutral → Increasing Alkalinity
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
CROP
Alfalfa
Almond
Apple
Barley
Bean
Bean, Lima
Beet, Sugar
Boysenberry
Broccoli
Cantaloupe
Cauliflower
Carrot
Celery
Cherry
Clover, Ladino
Clover, Crimson
Clover, Sweet
Corn
Grape
Grass
Lettuce
Onion
Oats
Pea
Peach
Peanut
Pear
Plum
Potato, Sweet
Potato, White
Radish
Rice
Sorghum
Spinach
Squash
Strawberry
Sunflower
Tomato
Trefoil, Birdsfoot
Turnip
Vetch
Walnut
Watermelon
Wheat
Nutrient Availability:
Phosphorus
Potassium
Iron
Manganese
Zinc
Bacterial Activity:
Nitrogen Conversion
Atmos.Nit.Fixation
Sulfur Oxidation

3. Neutralizing power of some common liming materials

Name	Analysis	Neutralizing Power
Lime	$CaCO_3$	100
Ground Limestone	80-95% $CaCO_3$	85-100
Ground Dolomitic Limestone	52% $CaCO_3$ 42% $MgCO_3$	95-108
Hydrated Lime	65% CaO	120-135
Marl	60% $CaCO_3$	50-90

Fineness of Liming Material

Particle Size	Efficiency Rating (Per Cent)
Material passes a 60 mesh sieve	100
Material passes a 20, not a 60 mesh sieve	60
Material passes an 8, not a 20 mesh sieve	20

Liming materials must be finely ground or they react with the soil too slowly to be effective.

4. Amount of liming material to use

-- varies by material used

-- varies by type of soil

-- varies by organic matter content of soil

Approximate Amounts of Different Liming Materials Required to Raise the pH Value One Unit on Various Soils

Soil	Ground limestone or marl lbs. per acre	Hydrated lime lbs. per acre
Light sands	1,500	1,100
Sandy loams	2,000	1,480
Loams	3,000	2,220
Silt and clay loams	3,500	2,590

For soils low in organic matter, reduce the above amounts by 25 per cent. For soils high in organic matter, increase these amounts by 100 per cent.

C. Computations, Conversions and Calculations

1. New fertilizer arithmetic

Traditionally, phosphorus and potassium analysis have been given in the form of P_2O_5 and K_2O. Many new recommendations are given on the basis of the elemental form rather than the oxide form. The conversion factors used in the various forms are as follows:

To convert P_2O_5 to P multiply P_2O_5 content by 0.44

To convert P to P_2O_5 multiply P content by 2.29

To convert K_2O to K multiply K_2O content by 0.83

To convert K to K_2O multiply K content by 1.20

2. Calculate the amount of available N, P_2O_5 and K_2O in fertilizer materials by first changing the per cent analysis into a decimal fraction. (Move decimal two places to left.)

For example, with ammonium sulfate, 21-0-0:

$$21\% = \frac{21}{100} = .21\# \text{ N per lb. of fertilizer}$$

Multiply decimal fraction x lbs. used to get the amount applied.

Example: .21 x 250#/A fertilizer = 52.5# N/A

Calculate the lbs. of N, P_2O_5 and K_2O in one ton of 6-24-8

6% N = .06 x 2000 = 120# N per ton

24% P_2O_5 = .24 x 2000 = 480# P_2O_5 per ton

8% K_2O = .08 x 2000 = 160# K_2O per ton

3. Calculate the cost per lb. of N, P_2O_5 and K_2O in fertilizers.

The student should remember that the customer buys fertilizers primarily for the nutrient contained and not for any side effects the fertilizer may have. Therefore, when a farmer pays \$2.50 for 100 lbs. of fertilizer that contains 21 lbs. of N, he is really paying \$2.50 for 21 lbs. and not for 100 lbs.

Step - 1 Calculate the number of lbs. of fertilizer nutrient in the sack, gallon or ton (see 2 on opposite page).

Step - 2 Divide the cost per sack, gallon or ton by the number of lbs. of nutrients contained therein.

Example: One ton of ammonium sulfate (21-0-0) costs $50.00.

Step - 1 .21 x 200 = 420# N per ton

Step - 2 $50.00 ÷ 420 = $.119 per lb/N (11.9¢).

4. Calculate the number of lbs. of fertilizer needed to apply a given amount of nutrient

It is a common practice for experimental stations to recommend that a given crop should receive a given number of lbs. of N, P_2O_5 or K_2O. The technician must be able to determine how many lbs. of different fertilizers would be needed to apply the correct amount of a given nutrient.

a. Amount required = total recommended ÷ lbs. of nutrient in one lb. of fertilizer.

Example: Assume that 75# of N/A is recommended for a given crop and we plan to use ammonium sulfate

75 ÷ .21 = 357# of ammonium sulfate per acre are needed to provide 75# N/A

b. If one divides the amount recommended by the amount of nutrient contained in a sack or ton of fertilizer, the answer will tell one how many sacks or tons are needed.

Example: 75# N recommended per acre and the farmer is using 21 - 0 - 0.

80# sack x .21 = 16.8# N per sack

75 ÷ 16.8 = 4146 sacks per acre

Example: One wants to fertilize 30 acres at the above rate 75#/A x 30 A = 2250# N will be required in total 2000# of 21 - 0 - 0 = 2000 x .21 = 420# N/ton 2250 ÷ 420 = 5.357 tons of ammonium sulfate required to apply 75# N/A on 30 acres.

Guide for the study of agricultural chemicals.

Note: The instructor will determine which chemicals are to be studied in depth. This selection of course depends upon the requirements of local areas and situations. Other items should be added to the guide as appropriate.

Chemical name (active ingredient)

Empirical formula

Chemical structure

Common name

Trade name(s) and major producer(s)

Melting point

Vapor Pressure

Solubilities

Odor

Color

Density

Physical state (liquid, solid, gas)

Corrosive action

Flammability

Stability

Compatibility

Suitable diluents

Concentrations

Purities/grades

Mixtures available

Industrial preparation

Formulations for use/additives used

Analytical methods

Analysis of mixtures

Phytotoxicity

Toxicity (LD_{50}, LC, ppm oral, dermal, acute, chronic)

Special hazards

Residues likely, tolerance limitations

Synergists possible for use

Intended general use (insecticide, fertilizer, nematocides, etc.)

Intended specific use

Antidotes and first aid

Factors which limit the effectiveness of the chemical (such as temperature, sunlight, water, etc.)

SUGGESTED TEACHING-LEARNING ACTIVITIES

1. Show film, "Making the Most of a Miracle." National Plant Food Institute. 27 min., color film.
2. Work problems with class using information gathered locally.
    a. Determine cost per lb. of N or P or K from various materials used locally.
    b. Determine how many lbs. of commonly used fertilizers would be required to supply the recommended amounts of nutrients for major local crops.
3. Gather fertilizer bags from local companies and note information contained thereon.
4. Show film, "What's in the Bag?" National Plant Food Institute.
5. Take a field lab to a fertilizer formulation plant and study their methods of formulating liquid and dry fertilizers. Take special note of what materials are used, why they are used, and how they are handled.

SUGGESTED INSTRUCTIONAL MATERIALS AND REFERENCES

Instructional Materials:

1. Obtain copy of the section of your state codes that deal with fertilizers.

2. Many major companies have charts, slide rule devices, and other gadgets to show how many lbs. of plant food are contained in a certain number of lbs. of fertilizer. Some gadgets show how many lbs. of fertilizer are needed to supply a certain amount of plant food per acre.

References:

Tisdale, S. L. and Nelson, W. L., Soil Fertility and Fertilizers. New York: The Macmillan Co.

The Fertilizer Handbook. National Plant Food Institute, 1700 K Street, N.W., Washington, D.C.

Western Fertilizer Handbook. California Fertilizer Association, 719 K Street, Sacramento, California.

McVickar, M. H., Using Commercial Fertilizers, Danville, Illinois, Interstate Printers and Publishers.

Donahue, Roy P., Soils, Englewood Cliffs, New Jersey, Prentice-Hall, Inc.

Dictionary of Plant Foods. Published by Farm Chemicals. Available through the Nitrogen Division, Allied Chemical and Dye Corporation, Hopewell, Virginia.

Miller, Harold F., Know Your Fertilizer, Miscellaneous Bulletin 209, Cooperative Extension Service, University of Kentucky.

Fertilizer Facts, Industrial and Biochemicals Department, E. I. duPont de Nemours and Co., Wilmington 98, Delaware.

IV. To learn how nutrients are classified into groups according to use or function of the element, to learn the functions of the elements in the plant growth process, and learn to recognize deficiencies or excesses of nutrients in plants.

Teacher Preparation

Subject Matter Content

Every effort should be made by the teacher to get the students to understand the functions of the nutrients in the plant growth process. If the student understands what the nutrient does, he will be better able to explain why the customer should use a certain material and also what amounts are required.

When the student understands the functions of the element in the plant, and how the element fits into the growth pattern, it is much easier to remember deficiency symptoms. Understanding and logic should replace note learning.

Each instructor should carefully review this portion of the study and pay particular attention to the material regarding deficiency symptoms. Delete that material not contributing to an understanding of the crops in your service area. Expand sections with particular significance in your area and use as many local examples as possible.

A. Classification of 16 Essential Plant Food Nutrients

1. On basis of amount used

C - H - O - Not generally classified under this category as they come from air and water and should not be deficient.

a. Primary plant food elements
N - P - K

b. Secondary plant food elements
Ca - Mg - S

c. Trace or Micro element. (Avoid the word "minor" as it connotes an idea of lesser importance. A good example is to ask how much the points in the ignition system of a car weigh. They may only make up a micro amount of the total weight, but they are essential if the car is to function properly.)

B-
Cl
Cu
Fe
Mn
Mo
Zn

2. Elements may also be classed as:

   a. Macro - N - P-K - Ca - Mg - S

   b. Micro - B - Cl - Cu - Fe - Mn - Mo - Zn

3. Classification of elements on the basis of their use in plants

   In many ways this is the most useful. The student gets an insight into how these elements function in the plant and this information helps the student understand why certain things happen with a deficiency of an element.

   a. Main structural elements

      C Form the carbohydrates,
      H fibers, cell walls, etc., that
      O give the plant its shape.

   b. Accessory structural elements

      N) Needed to make proteins
      P) and to give life to the
      S) cells.

   c. Regulators and carriers

      K) May or may not
      Ca) enter into plant
      Mg) cells.

      Example:

      Ask students to name one compound in plant tissue that is formed with K.

      These three elements help control pH within the plant, act as carriers of carbohydrates (ask why kernals of grain are shriveled when K is deficient) and help regulate the plant growth process. Mg is required in chlorophyl molecule.

   d. Catalyst

      B)
      Cl)
      Cu) Catalysts speed up or induce chemical
      Fe) reactions without entering into the
      Mn) reaction.
      Mo)
      Zn)

Example:

Both Zn and Fe are required in the formation of chlorophyl--yet neither is found in the molecule.

B. Function of Elements in Growth Process

1. Carbon

   a. Makes the cell wall and gives the plant strength

   b. It's the equivalent of steel super structure and brick walls - cellulose

   c. C also used in sugars - starches - fats

2. Hydrogen and Oxygen

   a. Essential both as water in plant for translocation, absorption, etc.

   b. O and H combine with C to make up over 90-95% of plant by weight

   c. Variation of amounts of C, H and O change the simple sugars to starches, cellulose, etc.

   d. C, H and O form basis for amino acids, protoplasm, and protein

   e. Little practical influence can be exerted by man

3. Nitrogen

   a. Essential element for building material in the plant and for amino acids which are elaborated into protoplasm - source of life

   b. Promotes rapid vegetative growth

      Tends to produce watery succulent growth

      Fine in lettuce - spinach - celery (leaf crops)

      May be bad in tomatoes and grains

   c. Promotes good color in vegetative parts

      Integral part of chlorophyll

      (C_{55} H_{72} O_5 N_4 Mg) Large molecule

d. Excessive N promotes too much vegetative growth and delays maturity.

e. Excessive N also causes lodging.

f. Excessive N also delays ripening in many fruit crops and makes poor shipping quality.

g. In some plants and for some diseases, N lessens resistance to diseases by making unnatural conditions in plant and by forming thin watery cell walls.

h. In other plants N stimulates growth and makes plants more resistant.

4. Phosphorus

a. Essential to all plant growth. Found in every cell necessary for formation of protoplasm. DNA - Deoxyribonucleic-acid and RNA - Ribonucleic Acid.

b. Phosphorus encourages root growth; more importantly, it stimulates development of root hairs.

c. Seeds usually richer than other parts of plant in phosphorus.

Phosphorus balances N in plant - increases grain compared to straw.

Strengthens straw and prevents lodging.

d. Phosphorus adds to quality of mature fruit - aids movement of sugar.

e. Weakening effects of N balanced by P and stronger, more normal growth promoted.

f. Involved in transfer of energy.

5. Potassium

a. N and P synthesized into compounds necessary for growth of plants. K is not.

b. K needed for formation of chlorophyl.

c. K aids starch formation and thus aids grains to get plump, full kernals.

Necessary for production and translocation of carbohydrates.

One of regulator or carrier elements.

d. Not sure just why but it aids vigorous growth and general well being of plant.

Balances P and N

Helps prevent lodging

Helps plant fight diseases

Without K plants can't seem to convert amino acids into proteins. N accumulates and can be toxic to tissues.

Like N an excess tends to delay maturity.

6. Calcium

-- Some doubt as to exact functions

-- Stimulates root growth and formation of root hairs

-- Essential in leaf development. Forms middle Lamellae of cell walls. Holds cells together - calcium pectate

-- Helps balance acids formed in plants - oxalic acid

-- Translocation of carbohydrates and protein influenced by Ca

-- Influences soil reaction and absorption of other nutrients

7. Magnesium

-- Constituent of chlorophyl $C_{55} H_{72} O_5 N_4 Mg$

-- Associated with translocation and metabolism of P

-- Associated with translocation of starches in stems and leaves

-- Essential to fruit production

-- Essential to formation of fats

8. Sulfur

-- Integral part of many amino acids

-- Promotes good green color

-- Essential for vigorous plant growth

-- Essential for module formation on legume roots

-- Essential for cell division and fruiting on some plants

-- May play a part in conversion of sun's energy to chemical energy

9. Boron

-- Required in extremely small quantities - excessive amounts readily damage plants

(Used as a soil sterilant)

-- Plays a role in protein synthesis

-- Influences Ca and K metabolism in plants

-- Required for nodule formation on some legumes

-- Influences vascular tissue formation

10. Iron

-- Essential for chlorophyl formation

-- Enters into oxidization process for release of energy from sugar and starches

-- Essential to synthesis of proteins contained in chloroplasts

11. Copper

-- Related to function of certain enzyme systems of plant

-- Extremely toxic if found in excess in forms available to plant

12. Manganese

-- Also toxic when found in excess

-- Essential in certain oxidative enzyme systems of plant. Effects oxidization of iron.

-- Plays part in certain nitrogen transformations

13. Zinc

-- Minute quantities needed

-- Zn is associated with certain process in chlorophyl formation

- Associated with formation of auxins which regulate growth
- Much is yet to be learned about the role of Zn in plant growth

14. Molybdenum
    - Associated with nitrate-reducing enzymes
    - Plays some role in fixation of N by Legume plants
    - Under high pH conditions often absorbed in amounts toxic to cattle
    - Acts as an electron carrier in enzyme systems which bring about oxidation - reduction reactions in plants

15. Chlorine
    - Latest element added to essential list
    - Stimulates growth of some crops
    - Almost always present in adequate amounts
    - Some crops have adverse effect from even moderate amounts of Cl. Tobacco.

C. Deficiency Symptoms

Many conditions may affect growth rate, color, etc. One must be cognizant of this fact before jumping to conclusions. A few mistakes have a habit of wiping out many good suggestions and destroy the salesman's image.

Develop with the class a list of conditions that induce characteristics similar to nutrient deficiency. Include such major items as the following:

1. Any factor that limits root growth and development
    - Nematodes
    - Excessive soil moisture
    - Soil insects
    - Root pruning "cultivator blight"
    - Drought
    - pH and salinity problems
    - Soil structure and hard pans

2. Low temperatures

3. Plant diseases

4. Insect attacks

5. Varietal characteristics and adaptability to area

Example: Some corn varieties do not show deficiency symptoms (purple color) of P even though P is deficient.

Other varieties of corn are naturally purple even though adequate P is available.

Instructor Note: Sell the idea that a little bit of knowledge can be dangerous. Emphasize that just because a plant has certain deficiency symptoms, other factors may be the cause. The inexperienced man may well be cautious in diagnosing problems unless he uses soil or tissue tests to back him up.

Common deficiency symptoms:

In spite of the fact that one may have many problems making recommendations based on visual observations there are some guides with which the technician must be familiar. The information contained below gives the general deficiency characteristics.

Make sure the students cover the specific deficiency symptoms of the crops in the area.

Nutrient	*Mobile or Immobile Element	Deficiency Symptoms
Nitrogen	Mobile	Light green to yellowish color. Show spindly growth "Firing" - leaves turn yellow then brown and die. Yellowing first begins at tip or margins on lower leaves.
Phosphorus	Mobile	Short, stunted growth. Purplish discoloration on some plants. Delayed maturity (can be dramatically shown only by putting out test plot containing P). Poor fruit or seed development.

Nutrient	*Mobile or Immobile Element	Deficiency Symptoms
Potassium	Mobile	Scorching of margins on older leaves. Mottling, spotting, streaking, or curling of leaves are common symptoms. Lodging often problem. Shriveled fruit or seed.
Calcium	Immobile	Terminal bud may die or fail to properly expand. Wrinkling of younger leaves. Excessive blossom and bud drop.
Magnesium	Mobile	Chlorotic condition at tip and between veins. Abnormally thin leaves. Leaves have tendency to curve upward.
Sulfur	Mobile	Deficiency symptoms similar to N.
Boron	Immobile	Terminal buds - first affected - necrotic condition causing die-back. "Brown heart" on root crops - roots often split. Many fruit crops develop internal and external "cork" characteristics.
Copper	Immobile	Wilting of terminal growth. Dieback follows. Chlorotic condition of leaves giving a bleached appearance on some crops.
Iron	Immobile	Acute chlorotic condition; leaves often turn almost white. Vein stays green longest. Youngest leaves first affected.
Manganese	Immobile	Chlorosis between veins of young leaves. Even smallest veins tend to remain green. Necrotic spots develop. Dwarfed growth.

Nutrient	*Mobile or Immobile Element	Deficiency Symptoms
Molybdenum	Older tissue first shows signs	Mottled appearance of leaves - stunted and yellowish. Curling and breakdown of leaf edges.
Zinc	Deficiency first appears on young tissue	Small terminal leaves. Deficiency called "little leaf" in some plants. Rosetting effect due to failure of proper cell elogation of stems. Dieback common. Thickened leaves. Chlorotic or mottled condition between veins.
Chlorine		Not normally deficient.

*Because many nutrient deficiency symptoms are similar, it behooves the student to know which elements are mobile and which are immobile. If the element is mobile it means that plant compounds break down and release the element for translocation to the growing tip. The deficiency symptoms for mobile elements appear first on the older tissue. Good examples of mobile elements and deficiency symptoms are N, P, and K deficiency on corn.

SUGGESTED TEACHING-LEARNING ACTIVITIES

1. Assign students to write and present report on deficiency symptoms of a crop grown in the area.
2. Using pots previously planted, note deficiency symptoms and other symptoms that may have appeared.
3. Show slides, "Deficiency Symptoms in Plants."
4. Gather and preserve specimen and slides that demonstrate the effects of nutrient deficiency.
5. Whenever the students are in the field, they should develop the habit of looking for stress symptoms on plants. Once these symptoms are discovered, every effort should be made to determine the specific cause of stress.

SUGGESTED INSTRUCTIONAL MATERIALS AND REFERENCES

Instructional Materials:

1. Posters and wall charts are available from many sources that demonstrate and picture nutrient deficiency symptoms.

References:

Hunger Signs in Crops. American Society of Agronomy and The National Fertilizer Association, Washington, D.C.

The Fertilizer Handbook. National Plant Food Institute, 1700 K Street, N.W., Washington, D.C.

Western Fertilizer Handbook. California Fertilizer Association, 719 K Street, Sacramento, California.

Tisdale, S. L. and Nelson, W. L., Soil Fertility and Fertilizers. New York: The Macmillan Co.

McVickar, M. H., Using Commercial Fertilizers, Danville, Illinois, Interstate Printers and Publishers.

Bear, Firman E., Soils and Fertilizers, New York: John Wiley and Sons.

1957 Yearbook of Agriculture Soil, U.S.D.A., Washington, D.C. Available through U. S. Government Printing Office.

Donahue, Roy P., Soils, Englewood Cliffs, New Jersey. Prentice-Hall, Inc.

V. To enable the technician to properly select and recommend various fertilizer chemicals to the customer.

Teacher Preparation

Subject Matter Content

Technicians must be familiar with the various fertilizer chemicals commonly used. They should know the advantages, disadvantages, and limitations of using different materials. The technician should be familiar with side effects such as pH changes, movement of the material in the soil, rapidity of uptake, toxic effects, safety precautions, and application methods.

This unit is one of the key units of the course. To be of service, and to be a good salesman, one must first know his product. The doctor has a wide assortment of medicines from which he may choose - some will do an excellent job, some will get by, and some will fail. The technicians' recommendations are no less important - at least as far as the customers' financial health and the technicians' ultimate well being are concerned.

Nitrogen, phosphorus, and potassium will be studied in greatest detail, but some attention will also be given to the secondary plant food elements. Only limited coverage will be given trace elements. The instructor should develop additional material for those elements critical in his locality.

A. Nitrogen

Introduction:

1. Approximately 80% of the air is N.
2. N is most commonly deficient nutrient even though the air over each acre of land contains 35,000 tons of N_2.
3. 98 to 99% of the soil N is in organic matter; only 1-22% is in NO_3 or NH_4 form.
    a. O.M. content of soils varies from a fraction of a per cent in some soils to over 80% in some peat soils.
    b. N release from O.M. occurs slowly - usually less than 5% released in any season.

c. Moisture, temperature, soil air, C:N ratio soil pH all affect N release.

d. (Quickly review N cycle.)

e. Crops that require large amounts of N (such as Irish potatoes) may require N fertilizers during cool seasons, even though the crop is grown on soils high in O.M.

4. N fixing bacteria

   a. Non-symbiotic or free living bacteria - only fix relatively small amount of N per year. Estimates vary but it is generally believed they only fix a few lbs. per ac. under most conditions.

   b. Symbiotic bacteria

      Rhizobia sp. - estimated they add 2,000,000 tons of N annually in United States.

      Legumes contain approximately 2.5% N and one may add from 50 to 100# or more of N per acre if the crop is plowed down.

5. Some N may be added to the soil with rain or snow. Less than 10# per acre annually.

6. Since N is an inert gas and the vast quantities in the air are not available to plants, and because we crop our land so heavily and because we can buy N cheaper than we can grow it, we will devote our time to studying chemical forms of N fertilizers.

   The technician should realize that N and other nutrients in manure are excellent for crops. However, N is N and the plant uses the element in the same way regardless of source. Our objective is to supplement the nutrient content of manure or provide nutrients in the cheapest, most convenient way in the quantity desired and at the time they will do the most good.

7. Regardless of the source, plants take up almost all of their N in two forms:

   a. Nitrate ion NO_3^-

   b. Ammonium ion NH_4^+.

      Both forms seem to be utilized about equally well although some plants tend to take up the nitrate form more readily and other plants utilize the ammonium form most readily.

8. Both forms are broken down within the plant and reduced to the NO_2 form. The NO_2 form is then assimilated into various amino acids.

Commercial N fertilizers are divided into four groups:

1. Nitrate fertilizers

   a. Sodium nitrate (nitrate of soda or Chilean nitrate)

      -- $Na\ NO_3$

      -- 16% N

      -- readily soluble

      -- leaves basic residue

      -- should not be used where Na may cause sodic or black alkali problem

      -- has been used extensively for side and top dressing for rapid results

   b. Calcium nitrate

      -- $Ca\ (NO_3)_2$

      -- 15.5% N

      -- leaves basic soil reaction - 100# of calcium nitrate is the equivalent of an application of 21# of lime.

      -- highly soluble - moves with soil moisture and gives rapid uptake.

      -- liquid calcium nitrate is often used for quick "shot" in irrigation water.

      -- cakes readily if exposed to air.

2. Ammonium forms of N - the great bulk of N fertilizers sold in the United States are in the ammonium forms.

   They are cheapest per unit of N and several have an advantage of ease of handling.

   The ammonium ion (NH_4^+) is held or fixed by clay and humus particles and does not move with water.

a. Anhydrous ammonia

-- NH_3

-- 82% N - highest analysis N material available

-- anhydrous means - "without water"

-- gas stored under pressure

-- toxic, hazardous material, must be handled with care and special equipment

-- readily reacts with water and must combine with water to form ammonium hydroxide

-- application is by injection 4" - 6" into moist soil pre-plant, side dressed between plant rows (if placed too close to roots it will burn them) or applied in irrigation water

-- NH_4^+ ion is not subject to leaching

-- leaves acid residue - it requires 147# of lime to neutralize 100# of anhydrous ammonia

b. Aqua ammonia

-- 20 - 30% - many states require all companies to standardize N content to some fixed figure such as 20%

-- anhydrous ammonia combined in water - so it is very similar

-- not under pressure - less hazardous but more bulky

-- should be injected into soil to prevent volatilization losses

c. Ammonium sulfate

-- $(NH_4)_2 SO_4$

-- 21% N and 24% S

-- made by absorbing ammonia in sulfuric acid base + acid -- salt

-- applied broadcast, side dressed. Often used as plow down material or in other pre-planting cultural operations

-- leaves acid residue, 110# of lime required to neutralize 100# of ammonium sulfate

d. Ammonium nitrate

-- $NH_4 NO_3$

-- 33.5% N

-- one half is in NO_3 form and the other half is in NH_4 form

Advantage is NO_3 moves with soil moisture into root zone for rapid uptake. NH is less subject to leaching and is gradually converted to NO_3 form and moves with moisture.

-- Safety precautions - keep away from sparks, open flames and oily materials. Explosive material under certain conditions. Reasonable precautions should be taken.

-- Acid residue - 61# lime required to neutralize 100# ammonium nitrate

e. Ammonium phosphates

-- Many grades

16-20-0
20-20-0
21-53-0
13-39-0

-- Di-ammonium forms contain 16-21% N.

-- Excellent for many crops when one desires a N - P fertilizer

Example: Grass; legume pasture

-- also widely used as starter fertilizer for many vegetable crops in the west. Placed below or below and to the side of seed

-- Acid residue

3. Snythetic organic nitrogen fertilizers

a. Urea

-- $CO(NH_2)_2$

-- 45-46% N

-- non-ionic so it moves with soil moisture until converted into the NH_4^+ form

-- highly soluble - often used in foliar sprays

-- immediate soil reaction is basic, but it eventually leaves acid reaction. Requires 71# lime to neutralize 100# area.

b. Calcium cyanamide

-- $CA\ CN_2$

-- 21% N

-- toxic to plants until it breaks down. 1# to 2# per sq. yd. applied at least 21 days prior to planting gives good weed control

-- expensive per unit of N

-- also used as defoliant

-- leaves basic residue. 100# is equivalent to the application of 63# of lime

4. Organic nitrogen materials

-- many organic products are sold for N fertilizers:

blood meal
fish meal and liquids
guano
cottonseed and other high protein materials

-- most are expensive per unit of N

-- special use in nurseries and in care and maintenance of potted plants

-- no salt residue

-- slow availability - less burning and leaching

B. Phosphorus

Introductions:

1. Plants need much smaller quantities of P than either N or K.

2. Taken up as orthophosphate ion $H_2\ PO_4^-$ and in lesser quantities as $HPO_4^=$

3. Also taken up as other forms but not usually in significant amounts.

4. Remember - P is necessary in nucleic acids - basis of life.

5. Much of the P found in soil is in unavailable forms - either as insoluble chemicals or "fixed" by the clay fraction of the soil.

6. Unlike N leaching is not a problem with P.

7. Analysis is in per cent of phosphorus pentoxide (P_2O_5) in sack.

   43.6% of P_2O_5 is elemental P

8. Apply in excess of actual crop needs as only a relatively small per cent is recovered in any crop year.

Phosphorus fertilizers are divided into four groups:

1. Natural phosphates
    - a. Phosphate rock
        - -- per cent P_2O_5 varies widely - usually 20 to 40%
        - -- solubility of P is low
        - -- sometimes used where cheap and the soil is acid
    - b. Bone meal
        - -- 20 to 28% P_2O_5
        - -- expensive so only used in special mixes
        - -- primary use today is in fertilizer mixes for potted plants and in nurseries
2. Processed or treated rock. Most important P fertilizers are from this source
    - a. Single super phosphate
        - -- 16-20% P_2O_5 (usually 18-20%)
        - -- accounts for over 80% of P fertilizers sold in the United States
        - -- contains 50% gypsum, $CaSO_4$

- manufacturing by treating phosphate rock with sulfuric acid.
- leaves neutral reaction in the soil
- commonly applied by broadcasting during preplanting operations and worked into the soil or top dressing on established stands

b. Treble or triple superphosphate

- 42-48% P_2O_5
- also called double or concentrated superphosphate
- phosphoric acid is used in treating phosphate rock so there is little or no sulfur in treble super
- advantage is less storage and handling per unit of P_2O_5
- generally more expensive per unit of P_2O_5 than superphosphate

c. Ammoniated superphosphates

- previously discussed under N
- N content in soil helps uptake of P in many cases so these materials are coming into more widespread use

d. Nitric phosphates

- T.V.A. is developing this process in the United States
- Acidulate phosphate rock with nitric acid
- 10-22% P_2O_5
- relatively new and not in widespread use

3. Chemical phosphate fertilizers

a. Liquid phosphoric acid

- H_3PO_4
- 52-54% P_2O_5

-- strong acid - leaves acid residue requires 110# lime to neutralize 100# fertilizer

-- commonly applied in irrigation water. Has the advantage of being able to meter the product into the water

-- expensive per unit of P_2O_5

4. By-product phosphorus fertilizers

   a. Basic or Thomas slag

      -- 8-10% P_2O_5

      -- has neutralizing effect on soil equal to 60 or 70# of lime per 100# material

      -- by-product of open hearth furnaces used in making steel

      -- use limited to areas near furnaces Alabama

5. Many other phosphate materials may be used but they constitute only a small fraction of the total. Where special crops or conditions require these materials, the instructor should include them at this point.

C. Potassium

Introduction:

1. Required in large amounts by plants; often found in larger quantity than N content of plant.

2. Absorbed as the K^+ ion.

3. Found in large amounts in many arid soils. Exceptions by areas and in sand, quartz, peat, and muck soils.

4. Most of soil potassium is in unavailable form.

5. Much of applied K may be tied up or changed into unavailable form.

6. Plants may contain 1-3% K. 3% is in excess of needs of plant and is called "Luxury consumption."

Potassium fertilizers

1. Muriate of potash or potassium chloride

   -- KCl

-- 60-62%. K_2O

-- Sometimes filler is added and it contains 50-60% K_2O

-- Over 90% of K_2O used in United States is from this salt. It provides the primary source of K_2O in mixed fertilizers

-- Neutral reaction in soil

-- Cannot be used on some crops due to their sensitivity to Cl

-- Cheapest per unit of K_2O

2. Sulfate of potash

-- K_2SO_4

-- 48-52% K_2O

-- Contains S but leaves a neutral reaction

3. Sulfate of Potash - Magnesia

-- 22-23% of K_2O + 18-19% MgO

-- Important material where both K and Mg are likely to be deficient

-- Potassium - magnesium sulfate is sold under the trade name of "Sulpo - Mag."

4. Potassium nitrate

-- 44-45% K_2O + 13% N

-- Very expensive so has limited use

-- Excellent for formulating mixes to be used with potted plants

D. Calcium

Introduction:

1. Important as a plant food, for its effect on pH, and for the role it plays in affecting soil structure and chemistry.

2. Absorbed by plants as CA^{++} ion.

3. One of most abundant elements in plant.

4. pH and Ca content of soil greatly affect the availability of P, Fe, Zn, Ma, and many other elements.

5. Ca levels affect micro-biological activity in soil.

Examples:

Adequate Ca is required for nodulation on legumes; nitrifying bacteria are inhibited at low pH levels.

Calcium materials

1. True lime or calcium oxide

    -- CaO

    -- Has neutralizing value of 179% compared to $CaCO_3$

    -- Hazardous - reacts with water

    -- Not commonly used

2. Calcium hydroxide or slaked lime

    -- $CA(OH)_2$

    -- Made by mixing lime and water

    -- Also called builders or hydrated lime

    -- Neutralizing value 136%

    -- Not commonly used

3. Calcium carbonate or agriculture lime

    -- $CaCO_3$

    -- Neutralizing value depends on purity of product and fineness of grind

    -- Consider it to have neutralizing value of 100%

    -- Marl - unconsolidated mixtures of clay and $CaCO_3$

4. Dolomite - Calcium - Magnesium carbonate

    -- $Ca\text{-}Mg(CO_3)_2$

    -- Ca and Mg both active and serve to effect pH as well as required for plant food

    -- Neutralizing value depends on purity-usually runs approximately 90%

5. Gypsum

   -- $CaSO_4$

   -- Contains both Ca and S so has little effect on the pH of soil

   -- Excellent to add Ca or S and not change pH

   -- Widely used on sodic (black alkali) soils in reclamation process. The calcium replaces the exchangeable sodium and the soluble sodium sulfate may then be leached.

E. Magnesium

Introduction:

1. Much less Mg is required than Ca.

2. Important in chlorophyl molecule. $C_{55} H_{22} O_5 N_4 Mg$.

3. Acts much the same as Ca in soil pH and chemistry relations.

4. Mg is found in small amounts in many fertilizer and liming materials.

5. Absorbed as Mg^{++} ion.

Magnesium materials: (previously discussed)

1. Dolomite

2. Potassium - magnesium sulfate

F. Sulfur

Introduction:

1. S found in many compounds of plants including a number of amino acids and oil compounds.

2. Responsible for many odors in plants. Garlic - mustard - cole crops.

3. May play a part in the conversion of sun's energy to chemical energy in the photosynthesis process.

4. S is absorbed as the sulfate, $SO_4 =$ ion.

5. May be absorbed through the leaves as sulfur dioxide, SO_2.

6. Deficiency symptoms are similar to N.

7. Considerable quantities of S may be added to the soil through rain and snow. Particularly so near areas of industrial concentration.

Sulfur materials:

Many materials contain sulfur and vast tonnages are added to the soil annually. Many sprays and dusts, gypsum and low analysis fertilizers contain S. A few of the more common materials are discussed.

Gypsum

-- Ofen added for its S content

-- Particularly good where one needs S but does not wish to lower Ph

-- S content dependent on purity. Usually 10-18% S.

-- Effectiveness depends upon % S and fineness of grind

-- Commonly applied in quantities of 500 to 4000 lbs. per ac.

-- Best results if incorporated into soil. May top dress sod crops and let rains carry it into soil

-- Excellent material to use on many crops due to Ca content as well as S. Peanuts, many legumes.

Soil Sulfur

-- S content may run as high as 95-99% pure S

-- Impurities may lower the per cent S to much lower levels.

-- Not generally applied to supply S. Much greater use in reclamation of sodic soils.

-- S deficiencies may be corrected with 100# per ac. or less

-- Reclamation may require 500 or more elemental S per ac.

Other fertilizer materials

-- If an S deficiency exists most soils are deficient in other elements as well as S.

-- Common sense and good practice dictates that one should apply the material that best meets the deficiency problem.

-- Examples of fertilizer materials selected for dual purpose are:

Ammonium sulfate 21% N, 24% S

Single superphosphate 20% P_2O_5 - 12% S

Potassium sulfate 50% K_2O - 18% S

G. Trace elements

Note to instructor: The trace elements tend to be deficient in soils by areas. In many cases a deficiency of a trace element may be the greatest single limiting factor in plant growth.

The instructor should prepare some introductory remarks on the element, give suggested materials, and characteristics of the fertilizers as they apply to the local condition.

SUGGESTED TEACHING-LEARNING ACTIVITIES

1. Collect samples of simple and mixed fertilizer materials. Note characteristics of each and be able to identify some of the commonly used fertilizers with specific characteristics.

2. Gather samples of lime, dolomite, gypsum, sulfur and other conditioners used in the area.

3. Add some sodium hydroxide to a clay soil solution and note how the particles are dispersed. Take half the above sample and add gypsum, shake both samples and note how rapidly each settles.

   Place filter paper in two funnels then pour the above solution into different funnels. Note the rate at which the water percolates through each. Allow the soil to dry in the funnels and note the difference in color and structure in each.

4. Gather local soil samples that have extremes in pH. Add amendments to half and allow the other half to remain in the natural state. Place in pots or cans and plant seeds. Fertilize, water, and otherwise handle both pots in the same manner.

5. Put out a fertilizer plot using nitrate, ammonium and urea fertilizers. Use the same amount of N on each. Note rapidity of response.

6. Have the student compile a chart showing the commonly used fertilizer materials used in the area on major crops. Note whether the use of the material is increasing, staying the same, or decreasing.

7. Take a field lab to the Extension Service or other reliable source and have them discuss the place and use of some of the major plant food materials.

SUGGESTED INSTRUCTIONAL MATERIALS AND REFERENCES

Instructional Materials:

1. Fertilizer materials.

2. Soil conditioning materials.

3. Sodium hydroxide, funnels, filter paper.

4. Fertilizer labels.

5. Clay pots, gallon cans (No. 10 size), or clean 1-quart oil cans.

References:

McVickar, M. H., Using Commercial Fertilizers, Danville, Illinois, Interstate Printers and Publishers.

Tisdale, S. L. and Nelson, W. L., Soil Fertility and Fertilizers. New York: The Macmillan Co.

The Fertilizer Handbook. National Plant Food Institute, 1700 K Street, N.W., Washington, D.C.

Western Fertilizer Handbook. California Fertilizer Association, 719 K Street, Sacramento, California.

Dictionary of Plant Foods. Published by Farm Chemicals. Available through the Nitrogen Division, Allied Chemical and Dye Corporation, Hopewell, Virginia.

Bear, Firman E., Soils and Fertilizers, New York: John Wiley and Sons, Inc.

1957 Yearbook of Agriculture Soil, U.S.D.A., Washington, D.C. Available through U. S. Government Printing Office.

Donahue, Roy P., Soils, Englewood Cliffs, New Jersey. Prentice-Hall, Inc.

How to Evaluate Agricultural Liming Materials, M. M. - 198, Cooperative Extension Service, The Ohio State University, Columbus, Ohio.

Soil Fertility and Fertilizer for Ohio Farms, Bulletin 395, Cooperative Extension Service, The Ohio State University, Columbus, Ohio. Reprinted 1965.

Walsh, Beatt, Hull and Wiese, *Lime and Fertilizer Recommendations for Field Crops*, Madison, Wisconsin: University of Wisconsin, 1962.

McGhee, Claude, *Plant Nutrition*, Morgantown, West Virginia, West Virginia University, 1964.

e

VI. To learn the place and value of various diagnostic tests in measuring nutrient content of plants and fertility levels of soils. To understand how these tests serve as another "tool" to help the technician make recommendations to his customers. To enable the student to set up and analyze field trials and exploratory plots.

Teacher Preparation

Subject Matter Content

This unit should serve to inform the student about the different types of tests available to help him properly satisfy his customers' needs. Information on soil and tissue tests; their advantages, disadvantages, limitations, and interpretation is covered. The student should understand that such tests constitute another "tool" which he may use to do his job. They should not be relied upon to give exact, definitive answers for there are too many variables in raising crops to reduce the problems to such simple terms.

A. Soil Tests

Methods of testing soils and the value of such tests vary widely in different areas. Some tests are valid and are accepted throughout the country; other tests may not show a correlation between the laboratory results and field trials.

The instructor should develop in depth those tests and methods that are used in his local area. This unit of study will cover some of the basic tests and practices generally followed.

1. Taking the sample

    a. No test is any better than the sample analyzed. If one takes one pound of soil per acre it represents approximately $\frac{1}{2,000,000}$ of an acre. It is obvious that the one pound sample must be as close as possible to representing the other 1,999,999 pounds. In many cases one or two pounds will represent 20 or more acres.

    b. Samples for nutrient tests are usually taken at 0-12". (Most will be 0"-6".) Samples for pH, salinity, and alkali conditions are often taken at deeper depths. Keep samples from different depths separate.

c. Soil probes or augers are preferred for taking samples at random places throughout the field. Usually limit the samples for a single test to areas of 5-20 acres.

d. Number the samples and keep record of where borings were made.

e. Boring should be thoroughly mixed and air dried before being tested.

f. Soil testing forms call for information which the technician should complete at the time the samples are taken. Such information may include:

-- Cropping history and yields

-- Crop growing or to be planted

-- Condition of crops

-- Fertilizer history

-- Liming history

-- Moisture conditions or irrigation practices

-- Soil type

-- More and more field men now ask the customer what his yield objectives are so they can fertilize to meet that objective

-- One doesn't fertilize a 75 bu. corn crop at the same rate one would fertilize a 150 bu. crop

2. Testing samples

a. pH tests - excellent, reliable tests; however, the technician must recognize that due to other chemical characteristics of the soil a given crop may grow differently on various soils even if all have the same pH.

-- Soils high in salts may be approximately neutral so one also tests for salinity in many areas

b. Electro-conductivity tests - to measure salts

-- A saturation extract is used to measure the flow of an electric current

-- The conductivity is measured in millimhos per centimeter. Symbolized as EC_e

-- The following chart shows the relationship between EC_e and plant growth

Salinity (EC., mmhos./cm. at 25°C.)	Crop Responses
0 to 2	Salinity effects mostly negligible.
2 to 4	Yields of very sensitive crop may be restricted.
4 to 8	Yields of many crops restricted.
8 to 16	Only tolerant crops yield satisfactorily.
Above 16	Only a few very tolerant crops yield satisfactorily.

-- An electro-conductivity of 1 millimho per centimeter of saturation extract is equivalent to approximately 4 oz. of table salt in 50 gallons of pure water. This has a salt concentration of 640 p.p.m.

-- The charts on the following page show the salt tolerance of some of our common crops. (Salt Tolerance of Plants, Agriculture Information Bulletin No. 283, U. S. Department of Agriculture.)

-- Soils with a high salt content are then analyzed for the types of salt present

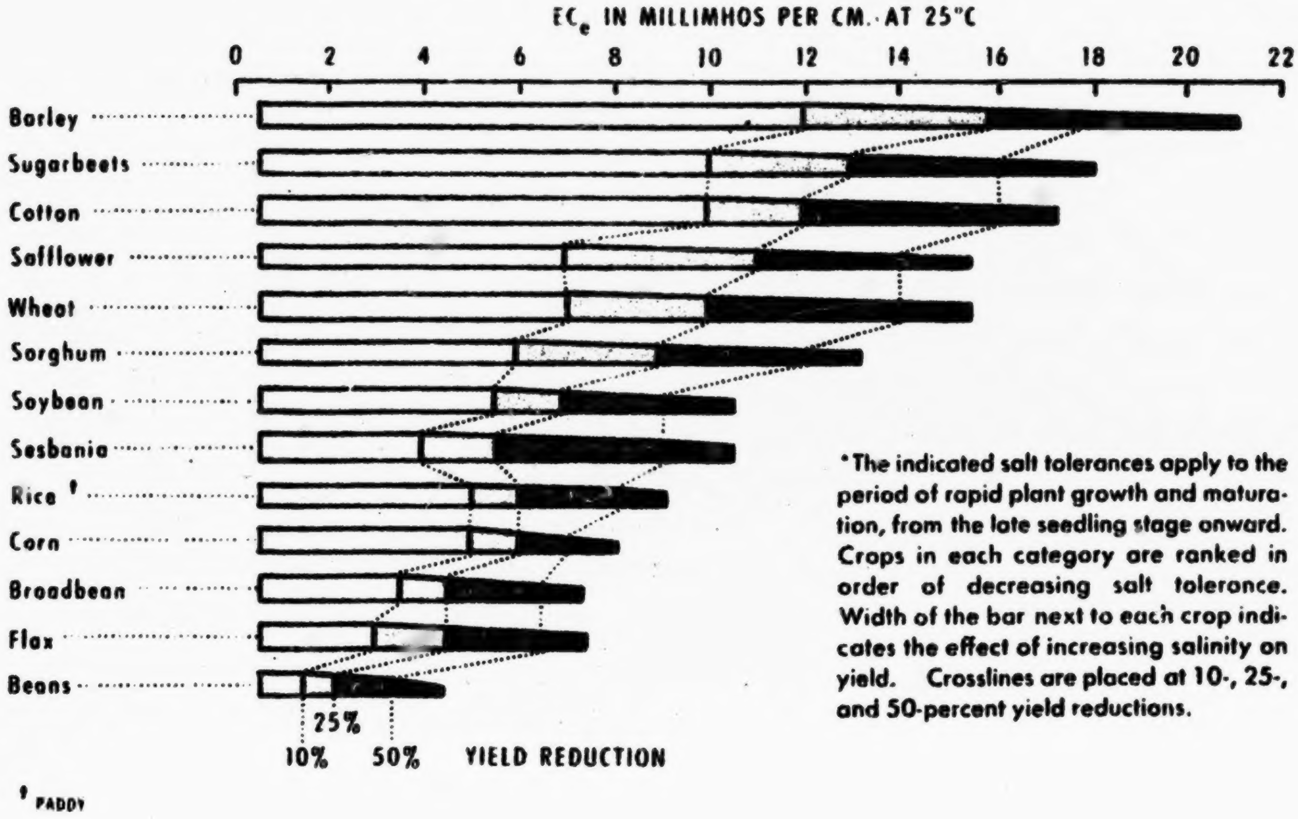
$Ca\ CO_3$	not harmful
$Na\ Cl$	harmful
etc.	

Instructor note - In many areas of the West, salinity tests are of major importance. This portion of the study may need expanding.

c. Other soil tests

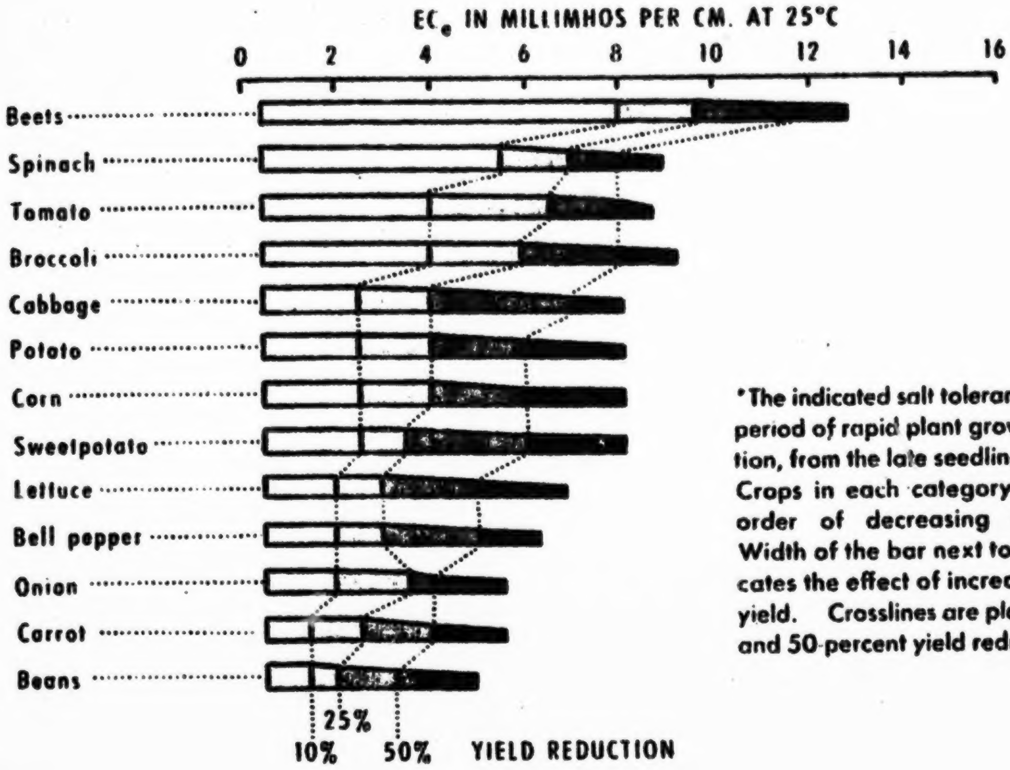
1. Extreme care must be taken to properly test the soil for valid results. In some areas, soil testing kits may give valid results. In other areas, the samples will have to be sent to a laboratory for testing.

SALT TOLERANCE OF FIELD CROPS*



*The indicated salt tolerances apply to the period of rapid plant growth and maturation, from the late seedling stage onward. Crops in each category are ranked in order of decreasing salt tolerance. Width of the bar next to each crop indicates the effect of increasing salinity on yield. Crosslines are placed at 10-, 25-, and 50-percent yield reductions.

SALT TOLERANCE OF VEGETABLE CROPS*



*The indicated salt tolerances apply to the period of rapid plant growth and maturation, from the late seedling stage onward. Crops in each category are ranked in order of decreasing salt tolerance. Width of the bar next to each crop indicates the effect of increasing salinity on yield. Crosslines are placed at 10-, 25-, and 50-percent yield reductions.

---

*U. S. Department of Agriculture, Agriculture Information Bulletin No. 283, "Salt Tolerance of Plants." Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402, Dec., 1964.

2. Equipment must be clean and good laboratory techniques must be carefully followed.

3. Extracting reagents may be weak or strong acids, weak or strong bases depending upon the test and methods used.

4. Extracting reagents must be un-contaminated and of proper strength. Remember these reagents are supposed to extract nutrients from the soil at some pre-determined rate that duplicates the roots ability to extract nutrients. If the reagent is too strong or too weak the results cannot be compared to the standard.

5. Tests for organic matter, nitrates, ammonia, phosphorus, potassium, calcium, magnesium, sulfur, and other elements are commonly made.

3. Interpreting tests

   a. Results are often reported in terms of:

      -- Parts per million (P.P.M.)

      -- Pounds of nutrient per acre in the plow layer

      -- High, medium, low, or blank tests

   b. Experience with the tests, the soil series, crop grown, and past results is necessary to properly evaluate the tests.

   c. Farmers and field men should not compare tests from different laboratories on the basis of the analysis obtained. For instance, Lab. "A" may say a soil contained 15 p.p.m. of Phosphorus and Lab. "B" may say the soil contained 5 p.p.m. of Phosphorous. Both labs may make the same recommendation regarding P fertilization, however.

   d. Soil tests can be used to indicate the trend of nutrient content over a period of years.

   e. Soil tests are also excellent means of determining if the soil has toxic amounts of elements.

   f. Soil tests do not tell one how much fertilizer will be needed although some good guides have been worked out for some areas.

   g. Soil tests can give one a good guide as to the amount of gypsum that will be required to correct a sodic condition.

B. Tissue Tests

Another tool to help evaluate nutritional problems is the tissue test. Chemical soil tests may not be able to duplicate the roots ability, or inability, to take up nutrients. Chemical tests of the plant tissue do give an accurate picture of what the plant has been able to take up.

1. Establishing "norms" with which to compare test samples

   -- Numerous tests must be made to determine what constituted an adequate level of a nutrient in healthy plants. Measured in P.P.M.

   -- What P.P.M. range indicated deficiency or yield depressing level?

   -- What range indicated an excess amount or luxury consumption?

2. Nutrient content varies with young and old tissue and at different times of growing season

   -- Always make sure test sample is taken from correct portion of plant.

   -- Test sample is usually a leaf, but in some crops one tests petioles, a portion of the stem and leaves or the stalks.

   -- Samples taken from the wrong type of tissue or from the wrong portion of the plant are worthless.

   -- Check to see that samples are taken at the correct period of plant growth.

3. Types of tissue tests

   a. Quick test field kits

      -- Colorimetric test in which one applies a chemical to a portion of plant tissue or drop of juice and checks color reaction against a key.

      -- Some of these quick tests are excellent.

      -- Many are worthless.

   b. Laboratory chemical tests

      -- Samples sent to commercial lab.

      -- Carefully analyzed.

      -- Colorimeter used to check color reaction or precipitate accurately.

c. Flame photometer

-- Portion of sample is carefully prepared.

-- A standard spectrograph is used to check the spectrograph of the sample.

4. Interpretation of tests. Consider all factors before jumping to conclusions on the basis of test readings.

-- An insect, disease, or root problem would inhibit the plants' ability to get nutrients from the soil even though there was an adequate nutrient content in the soil.

-- Soil moisture level - a recent irrigation could effect the uptake of nutrients - drought inhibits uptake.

-- General performance and vigor of the plant.

-- Time of day. Nitrate levels tend to be highest in the morning.

-- Level of other nutrients in plant has an effect on the plants' ability to take up and/or synthesize nutrients.

-- Yield desired. Heavy yield may demand higher levels of nutrient.

5. General comments

-- Nutrient tests and standards are very specific in many details.

-- In many cases tissue tests give accurate picture of nutrient content and indicate if plant is running low or if excessive nutrients are present.

-- Tests may indicate need for immediate fertilization to carry plant through heavy demand period.

-- In some crops it may be too late to add fertilizer, but one will know that next year the fertilizer program should be altered.

C. Pot Tests or Greenhouse Tests

Pot tests have limited practical value for evaluating soil nutrient content. They are excellent, however, for demonstrating deficiency symptoms and many other plant growth problems. Information on how to set up pot tests is included at the end of the unit.

D. Field Trials and Exploratory Plots

Deficiency symptoms, soil tests, and tissue tests all help to show what may be wrong. They have two major limitations:

1. They do not show how much fertilizer to add.

2. They do not carry the visual impact and reliability that sells the doubting Thomas on a fertilizer program.

Remember the statement "One good fact has destroyed many an argument." One of the best ways to get these facts is through carefully planned and accurate field trials. State experiment stations, fertilizer companies, and farmers have long relied on these trials as the basis of their recommendations and programs.

The students should be aware of how tests are set up, randomized, controlled, replicated and evaluated. If they understand the above they will be in an excellent position to base their recommendation on fact and defend their position.

Fertilizer trials used as a basis for general recommendations must be carefully carried out and replicated. Salesmen and many farmers carry out less elaborate and exacting trials and the results are often gratifying. Such tests, or exploratory plots, enable the customer to see what should or should not be done. These plots build up the rapport between the salesman and the farmer and certainly builds up the confidence of the farmer in the salesman.

1. Field trials or experimental tests

As the above terms are used in this paper one thinks of the types of tests experiment stations use to gather data upon which they base recommendations. The following factors are considered in setting up such tests:

a. Randomization

- -- The plots are put out at random. They are not put just on poor soil to show a good response.
- -- Try to locate in average spots and not in extreme areas.

b. Replication

- -- One test has little value.
- -- Tests that have been replicated 5, 10, 20 or more times become more valid as one averages the results.

c. Proper selection and application of the material

-- Tests are most commonly made for N, P, and K.

-- More and more tests are being made to check the response to secondary and trace elements.

-- Numerous tests are made to establish the most profitable amounts of fertilizer to use.

-- One portion of the plot serves as a check against which the trials may be compared.

d. Careful, accurate measurements

-- Size of test area - determine the fraction of an acre or acres involved.

-- Careful harvesting techniques.

-- Accurate measure of yield on dry weight or moisture corrected basis.

-- Determination of yield per acre.

-- Comparison of yield on check plot vs. the various trial plots.

-- Bushel weight, quality, grade, and feed nutrient tests are often made.

e. Miscellaneous

Throughout the test period observations are made on growth rate, moisture factors, disease and insect problems, maturity rate and for other pertinent information.

2. Exploratory or demonstration plots

An excellent way to demonstrate the values of fertilizers is to set up exploratory plots. Such plots are not as accurate as more carefully controlled tests, but they serve as an excellent means of educating students and customers.

a. Plots may be set up in numerous ways

-- Fertilize one strip with the test program and use the adjacent strip as a check.

- -- If you feel a farmer isn't using enough fertilizer you may convince him to go over one strip twice and skip the adjacent strip. His total fertilizer usage will be the same but he will have 3 trials. No fertilizer, standard treatment and the double treatment.
- -- An excellent plot for many crops may be set up similar to the plot shown on the opposite page.
- -- The plot may be made any size, but 20' x 40' is often used.
- -- The top 20' x 20' portion may be fertilized with an N fertilizer.
- -- Move 10' down from the top and fertilize the next 20' x 20' portion with P fertilizer.
- -- Next, fertilize the right half of the plot the entire length of the plot with a K fertilizer. This will be a 10' x 40' strip.
- -- The result of this treatment will give 10' x 10' fertilized areas with all combinations of N, P, and K.

When harvesting the plots, one harvests a measured area out of the center of each plot, then computes the relative yields per acre.

3. Harvesting plots

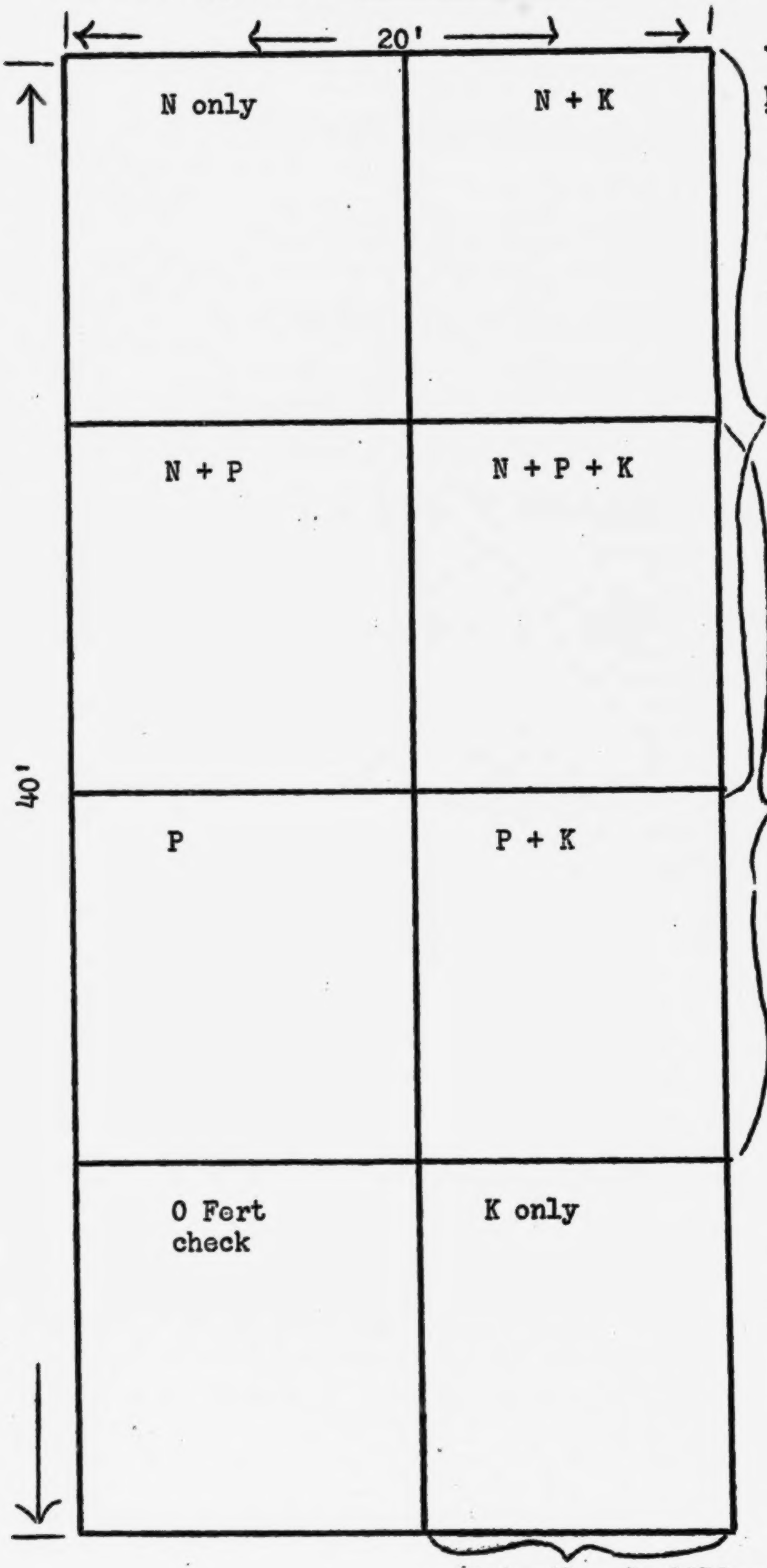
- -- Accurately measure the area to be harvested.
- -- Weigh the amount harvested from each plot.
- -- Record results.
- -- Compute final yield on dry weight or moisture corrected basis.

Heavily fertilized crops may have less dry matter on a percentage basis at harvest.

Grain crops are standardized at a given moisture percentage when computing yield.

Exploratory Plot Trial

Name____________________Address____________________
Location____
Crop____________________Soil pH__________Type__________
Date of Application____________________Stage of Growth____________________


20'
40'
N only
N + K
N + P
N + P + K
P
P + K
0 Fert check
K only

Gen. Info.

Materials used__________Rate Ac

Nitrogen fertilizer 20' x 20'

Phosphorus fertilizer 20' x 20'

Potassium fertilizer 10' x 40'

4. Fertilizer plot arithmetic

When one plans a fertilizer plot, there are two basic questions one must answer.

1. How many acres or what portion of an acre is in the plot?

2. How much fertilizer will be needed on the plot to equal the pre-determined rate per acre?

    a. Acreage in plot:

        -- Remember an acre is 43,560 sq. ft. (For estimating acreage it's good to remember that an acre is approximately 208' x 208')

        -- L x W of plot ÷ 43,560 = acres in plot

    b. Amount of fertilizer to be applied per acre x acres in plot = total lbs. of fertilizer needed

        Example:

        Plot 10' wide x 87' long. You want to apply 500# of ammonium sulfate per acre

        Acreage in plot = $\frac{10 \times 87}{43,560}$ = .02 acre

        Fertilizer needed - 500# x .02 - 10.0 lbs.

5. Calculating yields and harvesting the plot

    a. Usually one does not harvest the entire plot fertilized. To minimize any plant feeding from adjacent areas or unusual conditions at the ends of rows, harvest only the center portion.

    b. Carefully harvest crop and weigh yield.

    c. Yield per acre = yield from harvested portion of plot ÷ acreage in harvested portion.

        Example:

        In the previous example the plot was 10' wide x 87' long. Assume that it covered 4 rows of a particular crop. To measure results one would harvest only the 2 center rows, or a strip 5' wide. One would also move in from the ends before making the first harvest. Assume the harvested area was 80' long.

Total acreage harvested = $\frac{5' \times 80'}{43,560}$ = .009 acre harvested.

Assume the weight of the crop on the harvested area was 54#:

Yield per acre = $\frac{\text{plot yield}}{\text{ac. in plot}} = \frac{54}{.009}$ = 6000#

d. Miscellaneous plot and harvest information

-- Plots are harvested in many ways. One may harvest only a relatively few square feet by hand (the chance of error is greatly magnified) or one may use a combine or similar piece of equipment. If combines are used the fertilized swath should be considerably larger than the header on the combine. Accurate harvest and yield weights are a must.

-- Final results should be computed on a dry weight or moisture corrected basis.

-- Use the yield from the check plot as 100%.
$\frac{\text{Yield from test plot}}{\text{Yield from check plot}} \times 100$ = per cent increase from test plot.

-- Value of extra yield may be computed by subtracting the check plot yield from test plot and multiply the difference by the current market value of the crop.

-- One may then subtract the cost of extra fertilizer from the extra value of the test plot to get returns over fertilizer cost.

POT CULTURES

I. Technique to measure deficiencies in soils

  A. To test for one deficient element one must supply adequate amounts of other elements

    1. To compare phosphate deficiency one must compare

      a. Full treatment N-P-K

      b. Partial treatment N-O-K

    2. Difference in plant yield will then be a measure of phosphate supplying power of soil when N & K are not lacking or limiting

II. Requirements for study

  A. Select appropriate plants

  B. Collection of soil samples

  C. Assembly of equipment

  D. Treatment of soil with fertilizer

  E. Care of cultures

  F. Yield determination and interpretation of results

III. Making study

  A. Select appropriate plants--depends on:

    1. Climatic conditions

    2. Amount of soils used--small or large pots

    3. Adaptability of plants to growing space for roots.

    Freedom from pests and diseases, length of growing period, response to nutrients and similarity to req. of plants grown on soil tested.

    4. Partial list of plants used

      a. Romaine lettuce
      b. Barley
      c. Corn
      d. Sudan
      e. Sunflower

B. Soil samples

1. Top foot of soil for shallow rooted plants

2. 2nd foot for deep rooted plants

3. Number samples per field varies with size and prevailing soil conditions

4. Collected soils should be:

    a. Air dried

    b. Screened - 1/4" mesh

    c. Mixed thoroughly

    d. Measured into pots for treatment

C. Equipment and facilities

1. 6" flower pots best; tin cans 2½ to No. 10 size work fine. One-quart oil cans thoroughly washed with detergent soap may be used.

2. Balances to weigh fert. and yields. (Can be done with spoons and rules.)

3. Any fert. may be used - when using spoons use lower grade fert. $(NH_4)_2\ SO_4$ and single super.

4. Can use transplants.

5. Place cans in protected place and don't forget to water.

D. Fertilizer treatments

1. In order to insure that soils won't lack nutrients, applications will be heavier than those normally used in practice in fields.

2. In one state, for example, deficiencies can be corrected with the following applications:

    a. N - 200# per ac. 1000# $(NH_4)_2\ SO_4$

    b. P_2O_5 300# N per ac. 1500 - 1700 single super
    600 - 700 treble super

    c. K_2O 100# K per ac. 165 - 200# $K_2\ SO_4$ depending on analysis

3. These rates are symbolized as $N_2\ P_3\ K_1$ to label pots and indicates amount of nutrients used.

E. Care of culture

1. Following establishment of plants continuous attention to watering and growth habits must be given.
2. Observation and notes should be taken on plant color-growth and other characteristics of interest.
3. Record these and use them when yields are evaluated.

F. Yields

1. Measure the height of plant growth.
2. Cut off plants at ground level.
3. Weigh green.
4. Weigh in dried condition.
5. Weigh again for final dry weight yield.
6. RECORD ALL DATA

G. Interpretation

1. Don't apply results blindly to fields.
2. Field growth is less favorable and therefore results less pronounced.
3. Relative yields of dry weight on a percentage basis should be used to determine need. (Don't use green weight difference.)
   a. Compare all yields to those received by using full treatment of $N_2 P_3 K_1$.
   b.

Treatment	Dry Wt.	Relative Yield
$N_2 P_3 K_1$	910	100%
$N_2 P_0 K_1$	2.0	2/9 - 22%

   c. **Tentative scale of deficiencies**

Standard (Full Treatment)	Comparison	Deficient Nutrient	Definite Deficiency	Probable Deficiency	Not Deficient
NPK	PK	N	Less than 20%	20-50%	51-70%
NPK	NK	P	Less than 20%	20-50%	51-65%
NPK					

IV. Procedure

A. Preparation of pots and soils

1. Punch 4-6 holes in sides of can 1" above bottom.
2. Place screened soil up to about 1" from top. This is about 2# air dry soil in 2½ cans.
3. Put in wooden identification labels.

   Use PENCIL when pots are treated. Ink will smear from watering pots.

B. Addition of fertilizer

1. Following treatment gives best results
   - a. N_0 P_0 K_0 - No fert. - control
   - b. N_2 P_3 K_1 - Full Treat.
   - c. N_0 P_3 K_1 - Full Treat. - minus nitrogen
   - d. N_2 P_0 K_3 - Full treatment minus P
   - e. N_2 P_3 K_0 - Full treatment minus K
2. Amounts of each nutrient for 2½ cans 2# soils

   N_2 80 Milligrams of N

   P_3 - 120 Milligrams of P_2O_5

   K_1 - 40 Milligrams of K_2O
3. Fertilizers should be applied in sand or solution
   - a. Solution - (measuring spoons and liquid oz. cups)
     1. The following proportions give the required amount of fertilizer per pot using one liquid ounce of solution per 2½ can, or for approx. 2# of soil:

        N - $(NH_4)_2SO_4$ - 8 teaspoonfuls per gallon H_2O

        NH_4NO_3 - 6 teaspoonfuls per gallon H_2O

        P - Treble super - 7 teaspoonfuls per gallon H_2O

        K - Sulfate of potash - 1 teaspoonful per gallon H_2O

C. Planting and watering

1. Plant 10 barley seeds per $2\frac{1}{2}$ can or transplant two plants of romain lettuce 4 weeks of age to each pot.

2. Add sufficient water to completely wet the soil - but not to extent that excessive drainage occurs.

3. Add water during growing period as required.

D. Label pots

1. Wooden label should show:

    a. Name

    b. Treatment

    c. Date of planting

2. Also label can

...YOU WILL BE RESPONSIBLE FOR KEEPING YOUR TRIALS IN TOP CONDITION

SUGGESTED TEACHING-LEARNING ACTIVITIES

1. Take a field lab and collect, prepare, and ship soil and tissue samples to your state testing lab.

2. If valid quick tests are available, run several tests and interpret results.

3. Run some soil tests including tests using pH quick tests, pH meter, solubridge and nutrient tests if equipment is available.

4. Have each student set out an exploratory plot test on his own farm or on a given area.

5. Have the class set out several experimental fertilizer trials. Replicate trials so the students have the opportunity to see how tests vary.

6. Later on harvest a portion of the fertilizer trials, calculate yields per acre and returns per fertilizer dollar invested.

7. Visit any fertilizer trials conducted by fertilizer companies, extension service or others.

8. Have students put out pot tests following the procedure outlined for pot cultures at the end of the unit of study.

9. Show the film entitled "Plant Testing," American Potash Institute, 1102 16th St., N.W., Washington, D.C.

SUGGESTED INSTRUCTIONAL MATERIALS AND REFERENCES

Instructional Materials:

1. Various fertilizer materials for pot and field plots. (Many fertilizer companies will donate materials to make tests.)

2. pH quick test kits and pH meter.

3. Solubridge.

4. Soil and tissue test kits. A number of models are available from many sources.

5. Visual aids to use:

   "How to Take a Soil Sample"; 10 slides, N.P.F.I.

   "The Big Test"; 15 min. film - N.P.F.I.

References:

Tisdale, S. L. and Nelson, W. L., Soil Fertility and Fertilizers. New York: The Macmillan Co.

The Fertilizer Handbook. National Plant Food Institute, 1700 K Street, N.W., Washington, D.C.

Western Fertilizer Handbook. California Fertilizer Association, 719 K Street, Sacramento, California.

Bear, Firman E., Soils and Fertilizers, New York: John Wiley and Sons, Inc.

Spurway, C. H., Soil Fertility Diagnosis and Control. Published by the author, East Lansing, Michigan.

1957 Yearbook of Agriculture Soil, U.S.D.A., Washington, D.C.; Available through U. S. Government Printing Office.

Diagnosis and Improvement of Saline and Alkali Soils, Agriculture Handbook No. 60, U.S.D.A.; Available through U. S. Government Printing Office.

Donahue, Roy P., Soils, Englewood Cliffs, New Jersey. Prentice-Hall, Inc.

Walsh, Beatty, Hull and Wiese, Lime and Fertilizer Recommendations for Field Crops, Madison, Wisc., University of Wisconsin, 1962.

Wiese, R. A., and Walsh, L. M., Soil Samplers Manual, Madison, Wisconsin, University of Wisconsin, 1964.

Walsh, Leo M., Fertilizer Demonstrations on Corn, Small Grain, Hay and Pasture, Madison, Wisconsin, University of Wisconsin, 1961.

How to Sample Soils for Testing, Bulletin 388, The Ohio State University, Columbus, Ohio.

Salt Tolerance of Plants, Bulletin 283, U.S.D.A.

Plant Testing, American Potash Institute, 1102 16th Street, N.W., Washington, D.C., 1962.

Plant Analysis and Analytical Methods, Bulletin 766, California Agriculture Exp. Station, University of California, Davis, California, 1959.

Musgrave, O. L., How to Use Your Soil Test Results, Leaflet 194, Cooperative Extension Service, The Ohio State University, Columbus, Ohio.

Johnson, C. M. and Ulrich, A., Plant Analysis Analytical Methods, California Agriculture Exp. Station Bulletin 766, University of California, Davis, California.

SUGGESTED OCCUPATIONAL EXPERIENCES

If possible, have each student ride with a fertilizer salesman or soil testing representative when he collects and tests soil samples.

See if you can work in cooperation with the Extension Service in putting out one of their fertilizer trials, follow through on the tests, harvest, and calculate response.

VII. To gain a knowledge and understanding of the principles, concepts, and practices underlying the application and placement of fertilizers. To recognize that proper timing and placement of fertilizers is as important as what is used and how much fertilizer is used.

Teacher Preparation

Subject Matter Content

The unit deals with the commonly accepted practices of fertilizer placement; the advantages and disadvantages of different methods and problems encountered. Best results are obtained only if fertilizer nutrients are applied at the proper time, in adequate amounts, and in the best place for roots to take up the nutrient. This whole phase of fertilizers is fascinating because of the new information being developed from the use of new materials, combinations of materials, and better placement techniques.

Once again the instructor should make every effort to find out what is new and interesting in his service area. Tie in the specific practices used in the area with the accepted principles of fertilizer application and placement.

A. Fertilizer Application and Placement

Fertilizers are applied in many ways. The crop, soil, time of year, cost of application, nutrient applied, and stage of plant growth all affect when and how fertilizers are applied. We shall discuss some of the most common application methods.

1. Broadcast

-- Fertilizer is spread evenly over surface.

-- Often applied and then plowed down or disced into soil.

-- N fertilizers left on surface are subject to some volatilization losses.

-- Volatilization losses are affected by: pH, temperature, moisture, type of material used, amount of fertilizer applied, and surface conditions.

2. Drilled

-- Dry materials may be drilled several inches into soil, prior to, or at time of planting.

-- Anhydrous ammonia and aqua ammonia should be drilled or injected into moist soil, a depth of 6" - 8".

-- Large quantities of N materials are applied in this manner.

3. Band placement

-- Fertilizer is placed in bands to the side and below the seed or directly below the seed.

-- Remember - fertilizer is a salt so one must be careful where the fertilizer is placed and how much is used.

-- Some crops are "burned" if the fertilizer is placed directly below the seed. Other crops best utilize nutrients placed below seed.

-- Proper adjustment, accurate metering and constant checking should be made on equipment.

-- Banded fertilizers of N and P; N, P and K; or complete fertilizers with trace elements combined often give plants a quicker start.

-- Proper placement and ratio of different nutrients may allow one to use less fertilizer and get equal results.

4. Side dressing and top dressing

-- Post emergence fertilizer applications.

-- Top dressing usually refers to broadcast applications of fertilizers on established stands. Small grains, sod crops, etc.

-- Side dressing places fertilizer to the side of row crops. Usually drilled into soil with fertilizer shank or cultivated in.

-- When side dressing, one must be careful that fertilizer shanks are not placed too close to plant or severe root pruning may result.

5. Irrigation water applications

-- Cheap method of applying fertilizer as the job is done with irrigation.

-- Often provides the best way to fertilize crops during latter stages of growth.

-- Widely used to apply NH_3, aqua ammonia, many liquids and some dry materials such as calcium nitrate and urea.

-- Some loss of fertilizer in run off occurs.

-- Fertilization will only be as good as the efficiency of irrigation.

6. Foliar sprays

-- Most widely used with trace elements and chelated compounds.

-- Wide variation in results, recommendations, and practices.

-- Macro elements not usually applied in foliar sprays due to problems with foliage burn.

7. Transplant - starter solution

-- Weak fertilizer solutions usually with plant hormones added to help reduce transplant shock.

-- Some trace elements may be added in these solutions.

B. Application, Timing, and Availability of Nutrients

The student should recognize that a given element performs exactly the same function in a plant regardless of the fertilizer material used to supply the element. Stress should be placed on the words in the plant because fertilizer materials react differently in the soil and the plant may or may not be able to take up the applied nutrient.

Compounds vary in their ability to move in the soil. Because of these variations, one may use one material at the early stages of growth and use a different material to supply the same nutrient during later stages of growth. The student should be aware of these characteristics of fertilizer nutrients in order to best serve the needs of his future customers.

1. Nitrogen materials, timing, and movement in soils

a. --NO_3^- materials are not attracted to negatively charged clay and humus particles. Therefore, they move with water.

--NO_3^- may leach so one should not apply them unless immediate plant uptake is needed and desired. Excellent for fast response late in growing season or to get plants started.

--NO_3 may rise to surface of bed with capillary rise of water.

--On sandy soils, split applications of NO_3 fertilizer materials are often used to reduce leaching.

b. --Ammonia fertilizers are applied as NH_3 or ammonium (NH_4^+) forms. NH_3 quickly reacts with water to form NH_4^+ ion.

--NH_4^+ cation is attracted to negatively charged clay and humus particles and is held or "fixed" by these particles.

--Less subject to leaching or capillary rise than NO_3.

--Ammonia forms of N fertilizer applied during seed bed preparation, at planting and during the winter or early spring on many tree crops.

--Conversion from NH_4 to NO_3 forms will be a matter of one or two weeks to several months. Dependent on temperature (little conversion under 40° F), moisture, pH and oxygen content of soil.

--NH_4 and NO_3 fertilizers in irrigation water. NO_3 fertilizers move with the water through the bed and root zone of the plant. NH_4^+ ions are fixed in a relatively narrow area close to the irrigation furrow. NH_4 ions may not get to the root zone until converted to NO_3 ions which will be moved with the next irrigation.

c. --Urea fertilizer materials are soluble at first so the material moves like nitrate fertilizers in water. Urea is rapidly converted to ammonium form so it then acts like other ammonia fertilizers.

This unique characteristic makes urea fertilizers valuable on crops where one desires the material to move into the root zone, yet it is less subject to leaching than NO_3 fertilizers.

d. --The uptake of N by plants varies widely. In some crops it may not pay to add N after the mid point of the season. Some vegetable crops take up the vast percentages of total uptake during the last few weeks before harvest. Late applications of N on crops such as sugar beets can be detrimental to sugar content.

-- Carefully study the major crops in your area to see when fertilizer applications are recommended.

e. Volatilization losses

Severe losses of N may occur from dry and liquid N materials applied on the surface. Moisture, temperature, pH, soil make up, etc. effect losses.

N materials should be worked into the soil or carried into the soil by moisture as soon as possible to minimize volatilization loss.

2. Phosphorus fertilizers

Unlike nitrogen, leaching is not a problem with phosphorus materials. In many clay soils, fixation is the greatest problem and both initial and long-term recovery of phosphorus may be low.

The timing of P applications is also important. P is important to help plants get off to a vigorous start. Phosphorus fertilizers are also necessary on some soils when crops are planted during the cool period of the year. Plant grown on the same soil during warm weather may show no response to P fertilizers.

-- Best results from applied phosphorus comes from banding the material below or below and to the side of seed.

-- A combination of N and P will give better results and greater uptake than where P is used alone.

-- On permanent type crops, P is usually applied in late winter or early spring.

-- Phosphorus fertilizer applications are usually made in one treatment and generally one should not split the total amount into two applications.

-- On some soils and crops one massive application of P every two years may give better results than an equal amount applied in two yearly applications.

-- Where fixation is a problem one may have to apply phosphorus in quantities far in excess of the amount taken up by the crop.

-- Remember that phosphorus may become fixed within 6 inches of its placement in the soil.

3. Potassium

Potassium reacts in many ways in different soils. Generally it tends to be fixed and is less subject to leaching than N materials. Like P, potassium is generally applied in a single application early in the growing season, at planting, or when the seed bed is prepared.

--Crops vary in their need for K and their ability to extract K from the soil. Where crops are grown in rotation it is often best to apply the K to those crops that give greatest response.

Example:

In a corn-soybean rotation, usually fertilize corn only unless the soil has a definite deficiency of K. Peanuts often respond best if K fertilizers are applied to the previous crop rather than directly to the peanuts.

-- Do not apply excessive amounts of potassium to crops at two-year intervals. "Luxury consumption" is a problem and if the crop is cut and hauled away the material will be wasted. Legumes such as alfalfa may take up twice as much K as needed.

-- In some soils, however, a deficiency of K may only be corrected with a massive application of potassium and this treatment will be effective for several years.

Example:

In some California soils, 2000# of $K_2 SO_4$ was applied per acre to correct a K deficiency on almonds.

4. Miscellaneous

The instructor should work up a table, or other information, showing the timing, placement, and use of macro and micro nutrient fertilizers in his area. There is much variation in these factors and one should not rely on a set of general notes as a substitute for good instruction.

SUGGESTED TEACHING-LEARNING ACTIVITIES

1. Have the class divided into groups and make up a number of replicated trials. Plant corn or other small grain. Put fertilizer right with the seed, place the material 2" below and to the side of the seed in another set of pots, use N fertilizer alone in one set and use a complete fertilizer in another set.

2. Plant several rows of rapid growing crop such as radishes. Use various placement techniques (broadcast, branded, side-dressed). Leave one row unfertilized, then fertilize it later on to show how many plants need that early application to get them off to a rapid start.

3. If a micro nutrient is deficient in your area do some trials designed to show the response from those nutrients.

4. If possible, take a field lab to observe various application and placement methods, or have a follow-up study to see the results of different treatments.

SUGGESTED INSTRUCTIONAL MATERIALS AND REFERENCES

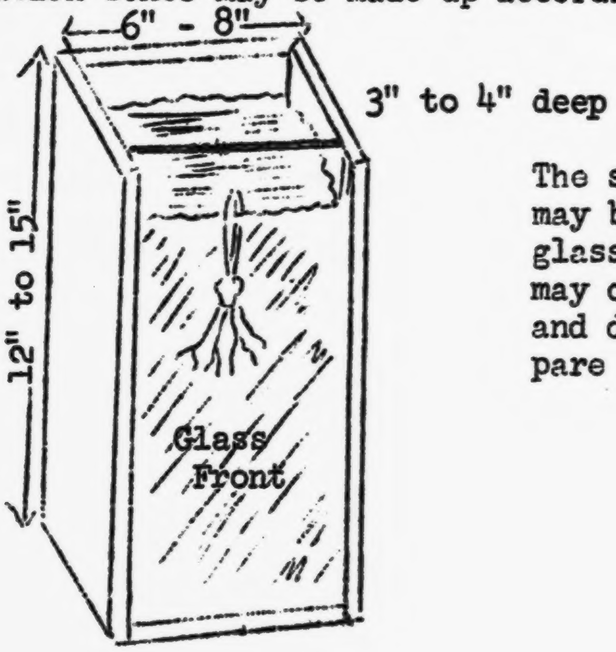
Instructional Materials:

1. Clay pots or clean one-quart oil cans.

2. Seeds.

3. Various fertilizer materials including chelated materials.

4. Good demonstration boxes may be made up according to the plan below.



The seed and fertilizer may be placed next to the glass and the students may observe root growth and development and compare various treatments.

5. "New Land" Film showing use and application of NH_3.

6. "How to Use N Solutions" - Farm Film Foundation.

References:

Tisdale, S. L. and Nelson, W. L., Soil Fertility and Fertilizers. New York: The Macmillan Co.

The Fertilizer Handbook. National Plant Food Institute, 1700 K Street, N.W., Washington, D.C.

Western Fertilizer Handbook. California Fertilizer Association, 719 K Street, Sacramento, California.

McVickar, M. H., Using Commercial Fertilizers, Danville, Illinois, Interstate Printers and Publishers.

1957 Yearbook of Agriculture Soil, U.S.D.A., Washington, D.C.; Available through U. S. Government Printing Office.

Donahue, Roy P., Soils, Englewood Cliffs, New Jersey. Prentice-Hall, Inc.

McGhee, Claude, Plant Nutrition, Morgantown, West Virginia; West Virginia University, 1964.

Walsh, Beatty, Hull and Wiese, Lime and Fertilizer Recommendations for Field Crops, Madison, Wisconsin; University of Wisconsin, 1962.

Soil Fertility and Fertilizer for Ohio Farms, Bulletin 395, Cooperative Extension Service, The Ohio State University, Columbus, Ohio. Reprinted 1965.

Plant Response to Fertilizers on a Saline Soil, Agriculture Exp. Station, New Mexico State University, 1964.

Fertilizer Facts, Industrial and Biochemicals Department, E. I. duPont de Nemours and Co., Wilmington 98, Delaware.

SUGGESTED OCCUPATIONAL EXPERIENCES

Have students placed in experience centers where they can obtain actual experience in determining rates of application as well as actually placing fertilizers in a field situation.

VIII. To gain an understanding and knowledge of approved practices and recommendations in using chemical fertilizers in a specific area. To develop skills and abilities needed to implement the practices and recommendations to satisfy the nutritional needs of the crops and to gain an awareness of the importance of knowing where and how to seek information for changing conditions.

Teacher Preparation

Subject Matter Content

Because there is such a wide variation in fertilizer practices and recommendations and because of the wide variations in crops grown, very little attempt will be made to spell out specific recommendations. This unit is designed to help the student to seek out such information, evaluate it in light of specific circumstances and apply his knowledge and judgment in making recommendations.

Much of the unit will be directed toward the development of a questioning mind on the part of the student. Once one asks the questions and defines the objective one must seek pertinent information. Current information is evaluated in terms of the specific conditions and objectives and then a decision must be made.

We have a rapidly changing technology and the practices accepted today may not be applicable tomorrow. The scientific approach to problem solving does not change, however, and the students should develop the habit of systematically analyzing and solving the problems.

In this unit it may be well to have the students find most of the answers. Perhaps more important than the specific answer is the source of information. Answers to amounts, kinds, when to fertilize and so forth change, but the sources of those answers generally remain the same.

The students should know where to look for information but then they must evaluate it. For instance, a general recommendation for fertilizing corn in a given area may be 100# N. A given farmer may have different soil, moisture, cultural practices and yield objectives, however, and 100# N would be entirely inadequate for his purposes.

Above all, require the student to think; make him aware of variations; make him unsure of rote answers. If all there is to making fertilizer recommendations is the ability to remember a set of figures, you don't need a salesman--you need a tape recorder!

A. The scientific approach to problem solving. The four basic steps to problem solving are as follows:

Define or limit the problem, be specific.

Gather all pertinent data.

Evaluate the information and weigh the alternatives.

Make a decision and recommendation.

1. Defining or limiting the problem

   -- Generally speaking, this will be a basic problem of meeting the nutritional needs of a specific crop.

   -- In some instances, however, one may be called out where some crop trouble exists. If it is a growing crop one may not be able to immediately tell if it is a nutritional problem or problems from disease, insects, soil conditions, drought, excess water, or some other condition.

2. Gather all pertinent data

   a. Much of the salesman's success will depend on his ability to get the necessary information.

   b. One should get the following information from the farmer:

      -- Yield objectives of the grower

      -- Crop history of the soil

      -- Past fertilizer practices

      -- Past yield results

      -- Cultural practices to be followed. Special attention should be given to unusual practices

      -- Fertilizer limitations due to market use of the crop

      Example:

      Some dehydrators, shippers or processors limit the amount of N to be applied to some fruit and vegetable crops.

      -- Variety and use of the crop to be grown

c. Diagnostic test data. Where valid soil and tissue tests may be made one should use the results of these tests as a valuable tool.

Remember - A doctor seldom prescribes a complete treatment on the basis of a blood test alone. The doctor uses the information as a portion of the facts he gathers to make his decision. If a single test gave all the answers, we could have a handful of technicians running around the state, taking blood samples and sending them to a single doctor in a state laboratory.

d. Accepted fertilizer recommendations. The salesman-technician must have a guide from which he may work. Fortunately, we have excellent guides available in most places in the United States. These general recommendations have been made on the basis of field trials and experimental studies.

Have the students list the sources to which they would refer to get information. The list should include such sources as:

-- State Experiment Station bulletins, pamphlets, news articles, etc. (Get them to write the station for some specific information.)

-- Local Agricultural Extension Agent or Farm Advisor. (Get name and address.)

-- Reputable farm management consultants.

-- Commercial firms - many commercial firms conduct extensive trials, either alone or in conjunction with experiment stations. Some of their recommendations may or may not agree with accepted practices. Here is an opportunity for limited field trials for evaluation of their recommendations.

-- U.S.D.A. publications - many of these have excellent general information and some are specific for given areas.

They may or may not be a good source of detailed recommendations for your area.

-- Personal experience or information from outstanding farmers. Just be sure that the information you have is factual and accurate. People have a tendency to forget if they don't have written records and the information you receive or remember may not be accurate.

-- Others - list according to your area.

3. Evaluate the information and weigh the alternatives

   a. In some areas one may be able to reduce the problem to simple arithmetic. For example - Charts are available that show the quantity of N, P and K in a given yield of a given crop. Soil tests show how much N, P and K is in the soil. One then calculates how much of the N, P and K is available and calculates the difference between what is available in the soil and the crop needs to determine how much of each nutrient may have to be added.

      If you can reduce the problem to such simple terms in your area, show the students how this is done using a specific example.

   b. Generally speaking, all of the agronomic knowledge one possesses must be brought together to evaluate and analyze the data.

   c. Experience will be one of your best teachers. Don't be too proud to call on experts to get their opinions.

4. Make a decision and recommendation

   As a salesman-technician, your success will be directly proportional to your ability to convince the customer that you know what you are doing.

   When making the recommendation quickly review the factors you considered in your deliberations. Discuss recommended practices and how you related his needs to these practices. Present alternative programs and the reasons for your specific recommendation.

B. Case Study

Have each of the students or teams of students, work out a case study (of different crops if possible). The studies should be presented to the class and the student should be prepared to "sell" his recommendation and defend his position.

C. Recommendations for major crops grown in the area. (Work out a basic set of recommendations for your area. The chart on the opposite page may be useful as a guide.)

__________ Community College

Agriculture Department

Crop	Usual Nutrient Recommendation Per Acre	Commercial Materials Used	Rate/Acre	When and How Applied	Miscellaneous Comments
Example: Sugar Beets	80-100# N	Sulfate of ammonia Ammonium nitrate Anhydrous ammonia	400-500# 250-300# 100-125#	Broadcast or drilled preplant, at planting or when plants are small	
	20-40# P_2O_5	Single superphosphate or 1:1:0 fertilizer such as 20-20-0	100-200#	Placed under seed at planting. Balance of N side dressed during early growth	Do not use N late in growing season as it depresses sugar content

SUGGESTED TEACHING-LEARNING ACTIVITIES

1. The key to the success of this unit is not what the instructor says, but what the students do.

2. Have the students contact the Extension Service, Exp. Station, fertilizer firms, or other reliable sources for information on fertilizer materials, placement, timing, and other miscellaneous information.

3. Make up a chart based on current recommendations given in the students' reports.

4. Assign some students to do research on micro nutrient use and results in your area.

5. Other students may give reports on results from various placement trials with fertilizers.

6. The students should present as many related factors as possible. They should indicate all circumstances surrounding the results so they better understand the factors that influence production of crops.

7. Some students should be assigned to check fertilizer recommendations for lawns, ornamental shrubs, and flowers.

8. Show examples of differences that may exist between experiment station recommendation and commercial recommendations and analyze possible reasons for such differences.

SUGGESTED INSTRUCTIONAL MATERIALS AND REFERENCES

Instructional Materials:

The instructor should have a complete set of bulletins and circulars that detail fertilizer recommendations for his area.

Local extension agents' pamphlets.

Experiment station bulletins and circulars.

Fertilizer company publications.

References:

Tisdale, S. L. and Nelson, W. L., Soil Fertility and Fertilizers. New York: The Macmillan Co.

McVickar, M. H., Using Commercial Fertilizers, Danville, Illinois, Interstate Printers and Publishers.

Hunger Signs in Crops. American Society of Agronomy and The National Fertilizer Assocation, Washington, D.C.

McGhee, Claude, Plant Nutrition, Morgantown, West Virginia; West Virginia University, 1964.

Walsh, Beatty, Hull and Wiese, Lime and Fertilizer Recommendations for Field Crops, Madison, Wisconsin, University of Wisconsin, 1962.

Soils and Fertilizers 1965 Guide for Fertilizer Dealers, Cooperative Extension Service and Agronomy Department, So. Dakota State University, Brookings, So. Dakota.

Soil Fertility and Fertilizer for Ohio Farms. Bulletin 395, Cooperative Extension Service, The Ohio State University, Columbus, Ohio. Reprinted 1965.

Walsh, Leo M., Fertilizer Demonstration on Corn, Small Grain, Hay and Pasture, Madison, Wisconsin, University of Wisconsin, 1961.

Plant Response to Fertilizers on a Saline Soil, Agriculture Exp. Station, New Mexico State University, 1964.

Fertilizer Facts, Industrial and Biochemicals Department, E. I. duPont de Nemours and Co., Wilmington 98, Delaware.

Sunset Magazine, "Lawns and Ground Covers"; published by Lane Book Co., Menlo Park, California.

Sunset Magazine, "Basic Gardening Illustrated"; published by Lane Book Co., Menlo Park, California.

SUGGESTED OCCUPATIONAL EXPERIENCE

If possible, tie in work on this unit with the unit on fertilizer trials and tests.

In conjunction with fertilizer company or extension service, set up trials on fertilizer amounts, placement, timing of application or micro nutrient trials.

IX. To acquire knowledge and skills to handle, transport, and store chemical fertilizers lawfully and safely. To acquire ability to properly calibrate basic fertilizer equipment.

Teacher Preparation

Subject Matter Content

This unit is designed to make the student aware that the fertilizer industry is governed by standards and laws. The students should know of some of the basic laws and should also know where to look for information and enforcement of laws.

Most fertilizer materials are safely handled, relatively speaking. The student should know and understand that some materials are definitely hazardous and one must exercise considerable care in handling these products. The application, transporting, and storing of chemicals can be a dangerous activity if one fails to observe correct procedures. The instructor should stress the fact that these are chemicals; some are extremely hazardous; others less hazardous; but all should be properly handled.

The student should also be able to calibrate fertilizer equipment to make sure the proper amount is applied. The applicator may be held liable for crop damage resulting from excessive applications.

A. Fertilizer laws, control and regulation

States vary in their regulations and enforcement practices governing fertilizer materials. The Association of American Fertilizer Control Officials was formed in 1946 to promote uniform and effective legislation, definitions, rulings, and enforcement of laws relating to the manufacture and sale of fertilizers. This organization and other state groups function to protect both the buyers and the industry from those who seek to practice fraudulent methods.

The State Department of Agriculture usually is the agency charged with the responsibility of enforcement of state laws. You may get the name and address of the agency in charge of laws and enforcement in your state by writing to The Association of American Fertilizer Officials, B. D. Cloaninger, Sec.-Treas., Clemson, S. C. The association publishes an annual report of fertilizer terms and state fertilizer control officials. The annual cost - $2.00.

B. Some Hazardous Fertilizer Materials

1. Ammonium nitrate - In 1947 two ships were blown up off the coast of Texas from an explosion of ammonium nitrate. If one follows the following rules there is no need to fear ammonium nitrate:

    a. No open flames or smoking should be permitted where ammonium nitrate is stored.

    b. Keep ammonium nitrate away from steam pipes, electric wiring, and combustible materials. Gasoline, oils, paints, and sulfur are especially bad.

    c. Store in well ventilated building.

    d. Spilled material should not be rebagged if it has become contaminated. Use immediately or destroy if mixed with combustible material.

2. Anhydrous ammonia

    Ammonia is a hazardous material and loss of life or severe physical damage may occur if it is not properly handled.

    a. Store only in suitable containers.

    b. Observe precautions and follow all recommendations in adjusting and using equipment.

    c. Make sure proper metering devices, orifice size, etc., are used when applying NH_3.

    d. Avoid contact with eyes or skin.

3. Phosphoric acid

    Many acids are extremely hazardous. Handle carefully and only use suitable containers. Avoid any contact with eyes or skin.

C. Application of Fertilizers

1. For profitable usage, application of fertilizers must be made in such a manner that:

    -- There is no injury to the roots, foliage, or seed.

    -- No salt injury occurs from excessive application or improper placement.

    -- Plants are not damaged by the equipment.

-- All parts of the field receive the correct amount of fertilizer and either excessive applications or "skips" are eliminated.

2. Calibrating liquid fertilizer injections

Formula: $\text{Ozs. per } 100' = \frac{\text{G.P.A.} \times \text{S.}}{3.4}$

-- G.P.A. = gallons per acre

-- S = swath in feet

Example: You want to apply 150# of N/acre using aqua ammonia (which has 1.5 lbs. N/gallon) with a 10 ft. swath. GPA is $\frac{150}{1.5} = 100$.

$\text{Oz.}/100' = \frac{100 \times 10}{3.4} = \frac{1000}{3.4} = 294$

This way you calibrate the entire swath, not just an individual shank. And you do not affect injection while you are calibrating.

Remember that the swath is the width of land covered on each pass (not the width of tool bar and not the distance between outside shanks).

On preplant rigs having equally spaced shanks, it is the distance between shanks times the number of shanks. Say you have 24 shanks, 12" apart -

Swath is $\frac{24 \times 12}{12}$ = feet

On side dress rigs, which do not usually have equally spaced shanks, it is the distance between rows times the number of rows. Say you apply on 4 rows 30" apart -

Swath is $\frac{4 \times 30}{12}$ = 10 feet

Note: In the above formula the word "ounce" is used to describe 1/16 of a pint. As there are 8 pints to a gallon, the "ounce" is 1/128 of a gallon. So the measurement in the example in gallons would be $\frac{294}{128}$ = 2.3 gallons per 100 ft.

The calibration chamber should, therefore, have a capacity of about 3 gallons, or about 700 cubic inches. A chamber 6" in diameter and 25" high is about right!

3. Calibrating dry fertilizer application

-- $\frac{\text{Amount applied in lbs.}}{\text{Acres}}$ = lbs. per acre

To calibrate a drill or broadcaster, one should first adjust the machine in the shop. To determine how much of an area is covered use the following formula:

a. $\frac{\text{Pi} \times \text{D. X. T.} \times \text{W}}{43{,}560}$ = Acres

b. $\frac{\text{Amount applied}}{\text{ac}}$ = lbs.

Pi = 3.14

D = Diameter of drive wheel in feet

T = Number of full turns of drive wheel

W = Width of fertilizer spreader in feet

Example:

One has a 10' easy flow spreader with 30" wheels. Fill the hopper with fertilizer and turn the drive wheel five full turns. Catch the fertilizer and weigh. In this example we will say that 4.5# of fertilizer was distributed in five turns of the wheel.

$\frac{3.14 \times 2.5 \times 5 \times 10}{43{,}560}$ = .009 acres would have been covered in five turns of the drive wheel.

$\frac{\text{4.5 lbs. fert.}}{.009}$ = 500# fert. applied per ac.

If one used a four row side dressing applicator and the fertilizer came down in four shanks one should catch the fertilizer from each shank and weigh separately to check for even application.

Remember the width of the swath is the distance between shanks times the number of shanks. Four shanks, 2½ feet apart would be:

4 x 2.5' = 10' swath

SUGGESTED TEACHING-LEARNING ACTIVITIES

1. Take a field lab to a local fertilizer company. Discuss handling of NH_3, other liquid and dry fertilizers. Have them discuss their safety regulations and precautions.
2. Check out procedure used to calibrate NH_3 injection. If possible, do this on a farm where the material is being applied.
3. Calibrate the flow of fertilizer from an easy flow, or side dress fertilizer rig. Follow with field check under actual operating conditions.

SUGGESTED INSTRUCTIONAL MATERIALS AND REFERENCES

Instructional Materials:

1. Industrial accident commission charts, and data on accidents.
2. State safety code and regulations.
3. Scales, tarps, bags, etc. to measure fertilizer applications.

References:

The Fertilizer Handbook. National Plant Food Institute, 1700 K Street, N.W., Washington, D.C.

Western Fertilizer Handbook. California Fertilizer Association, 719 K Street, Sacramento California.

Tisdale, S. L. and Nelson, W. L., Soil Fertility and Fertilizers. New York: The Macmillan Co.

McVickar, M. H., Using Commercial Fertilizers, Danville, Illinois, Interstate Printers and Publishers.

Donahue, Roy P., Soils, Englewood Cliffs, New Jersey. Prentice-Hall, Inc.

SUGGESTED OCCUPATIONAL EXPERIENCES

"Talking is Not Teaching." Place students in work experience centers where they will receive specific practice in the calibration and operation of fertilizer equipment.

X. GLOSSARY OF SOME COMMON AGRICULTURAL CHEMICAL TERMS, SELECTED REFERENCES, AND A GUIDE FOR SPECIFIC DEMONSTRATIONS AND USE OF VISUAL AIDS

A. Glossary

1. Acid Forming Fertilizer
   Fertilizers capable of increasing the residual acidity of a soil.

2. Acid Soil
   A soil giving an acid reaction (below pH 7.0). Often called "sour" soil.

3. Acidity, Active
   The activity of hydrogen ion in solution.

4. Acidity, Potential or Total
   The amount of exchangeable hydrogen ions in a soil that can be freed in the soil solution by cationic exchange.

5. Adsorption Complex
   The group of soil particles which are capable of adsorbing materials. The organic matter and colloidal clay form the greater part of the adsorption complex; the materials in silt-and sand-size have little ability to adsorb nutrients.

6. Alkali Soil
   Soil which has a pH of 8.5 or higher and/or 15% exchangeable sodium.

7. Ammonia Fixation
   Adsorption of ammonium ions by soils or minerals so they are not readily exchangeable.

8. Ammonification
   Production of ammonia as a result of the decomposition of organic nitrogen compounds.

9. Anaerobic
   Living or active in the absence of free oxygen.

10. Anions
    Negatively charged atoms or groups of atoms: ex NO_3^-, OH^-.

11. Biological Mineralization
    Conversion of an element occurring in organic compounds to the inorganic form as a result of biological decomposition.

12. Buffering Capacity
    The ability of a soil, or solution, to resist change.

13. Cations
    Positively charged atoms or groups of atoms such as K^+, Ca^{++} and NH_4^+.

14. Cation Exchange
The interchange between a cation in solution and other cations on the surface of a colloidal particle.

15. Chelated Compounds
Nutrient elements reacted with organic compounds to put them in a less active ionic form. "Claw" like form does not allow ions to be tied up by soil particles.

16. Chlorosis
Loss of chlorophyl in plants causing the plants to turn yellowish or pale green.

17. Compost
Organic residues which have been piled, moistened, and allowed to decompose.

18. Conditioners
Materials added to fertilizers to prevent deliquescence or improve handling or spreading qualities.

19. Deliquescence
The act of absorbing moisture from the air and becoming fluid. Fertilizers such as Calcium Nitrate may absorb moisture and later dry and cake.

20. Denitrification
The biological reduction of nitrate to nitrogen gas. Occurs under anaerobic soil conditions.

21. Dolomite (Calcium-Magnesium Carbonate)
Used to neutralize acid soils and as a source of calcium and magnesium.

22. Fertilizer
Any organic or inorganic material of natural or synthetic origin which is added to a soil in an attempt to provide plant nutrients.

23. Fertilizer-Analysis
Designates the percentage of nutrient composition of the product.

24. Fertilizer-Formula
The amount and kind of fertilizer materials used in making a mixed fertilizer.

25. Fertilizer Grade
The minimum guaranteed percent of plant-nutrient content: usually in terms of total nitrogen (N), available phosphoric acid (P_2O_5), and water-soluble potash (K_2O). Some firms now give the percent of elemental P and K rather than the oxide form.

26. Fixed Phosphorus
Phosphorus which has changed to less soluble forms as a result of reaction with the soil; "tied up" by the soil.

27. Green Manure
A crop grown for the purpose of being turned under while green, or soon after maturity, for improving the soil.

28. Guano
The manure of sea birds or bats. The name is sometimes given to other fertilizers having approximately the same composition.

29. Gypsum
Calcium sulfate. Used as an amendment on sodic soils. Does not change pH of other soils.

30. Humus
Residue from decay of soil organic matter.

31. Immobilization
The conversion of an element from inorganic to organic combination in microbial or plant tissues. The nutrient is no longer available to plants.

32. Ion
Electrically charged atom - anions are negatively charged; cations are positively charged.

33. Lime
Agricultural lime is usually calcium carbonate. True lime is CaO. Both are used to raise the pH of the soil.

34. Marl
Earthy deposit of $CaCO_3$.

35. Mineralization
The conversion of an element that is immobilized in some organic combination to available form as a result of microbial decomposition.

36. Nitrification
The biological oxidation of ammonium salts to nitrites and the further oxidation of nitrites to nitrates.

37. pH, Soil
The negative logarithm of the hydrogen-ion activity of a soil. The degree of acidity (or alkalinity) of a soil. The acidity or alkalinity is expressed on a scale of 0-14.

38. Ratio
In terms of fertilizers ratio refers to the relative amount of N, P_2O_5 and K_2O reduced to the lowest common denominator.

39. Reaction, Soil
Degree of acidity or alkalinity in the soil. Descriptive terms commonly used are: extremely acid, below 4.5; very strongly acid, 4.5 to 5.0; strongly acid, 5.1 to 5.5; medium acid, 5.16 to 6.0; slightly acid, 6.1 to 6.5; neutral, 6.6 to 7.3; mildly alkaline, 7.4 to 7.8; moderately alkaline, 7.9 to 8.4; strongly alkaline, 8.5 to 9.0; very strongly alkaline, 9.1 and higher.

40. Rhizobia
The bacteria living in nodules or legume roots in symbiotic relationship. They are capable of fixing free atmospheric nitrogen.

41. Saline-Alkali Soil
Soils high in salts and with 15% or more exchangeable sodium.

42. Saline Soil
A nonalkali soil containing sufficient soluble salts to impair its productivity. pH is usually less than 8.5.

43. Sodic Soil

See alkali soil.

44. Soil Amendments
Materials added to the soil to raise or lower pH and/or improve soil condition and structure.

45. Soil Salinity
The amount of soluble salts in a soil usually expressed in terms of percentage or parts per million.

46. Soil Solution
The aqueous solution existing in equilibrium with a soil at a particular moisture tension and whose chemical composition is determined, not only by soluble electrolytes and nonelectrolytes, but also by direct disassociation of ions on the surfaces of the soil colloids.

47. Symbiosis
The living together in more or less intimate association of two dissimilar organisms to the mutual benefit of both.

48. Unit of Fertilizer
Correctly refers to one per cent of a ton. Often used for one pound. Example: 40 units per acre meant 40# per acre of a particular element.

B. Visual Aids

The following list of film strips, slides, and moving pictures may be used as a guide to help the instructor select materials that may be useful in his teaching program. The materials should be carefully screened to be sure they are applicable to your area.

Title	Source	Use With Unit	Date to be Shown	Comments
Slides and Filmstrips				
1. Soils, Plants, Nutrition, and Fertilizers (29 slides)	National Plant Food Institute, 1700 K St., Washington, D.C. 20006			
2. How to Take a Soil Sample (10 slide)	Ibid.			
3. Nutrient Deficiency Symptoms in Plants (35 min. slides)	Ibid.			
4. Potash Deficiency Symptoms (22 slides)	American Potash Ins't., 1102 16th St., N.W., Washington, D.C.			
5. Safe, Efficient Fert. Placement (40 slide)	Ibid.			
6. Making Forage Fertilizer Pay (46 slide)	Ibid.			

Title	Source	Use With Unit	Date to be Shown	Comments
7. Fertilizing Both Small Grains and Legume Seedings (41 slides)	*Ibid.*			
8. Successful Alfalfa - You Can Grow It (40 slides)	Ibid.			
9. Ten More Bushels of Soybeans (51 slides)	*Ibid.*			
10. What's Wrong With My Corn? (45 slides)	*Ibid.*			
11. Hunger Signs in Corn (35 mm film strip)	Dekalb Agric. Assn., Dekalb, Illinois			
Films				
1. Making the Most of a Miracle (27 min.)	National Plant Food Institute, 1700 K Street, Washington, D.C. 20006			
2. What's in the Bag? (17 min.)	*Ibid.*			
3. The Big Test (15 min.)	*Ibid.*			

Title	Source	Use With Unit	Date to be Shown	Comments
4. Growing Alfalfa Successfully (25 min.)	American Potash Inst., 1102 16th St., N.W., Washington, D.C.			
5. Good Alfalfa Requires Good Fertility (10 min.)	*Ibid.*			
6. How to Use N Solutions (14 min.)	Farm Film Foundation, 1731 Eye St. N.W., Washington, D.C.			
7. Phosphorus: Key to Life	West Virginia Univ. Film Library			

Guide for Fertilizer Demonstrations

Classroom demonstrations are excellent means of increasing student interest as well as an effective method of teaching. Simple fertilizer demonstrations may be set up using some of the following suggestions:

1. Equipment:

   a. Containers: Large juice cans (1 qt. size);) All work
   Clean, 1 qt. oil cans;) excellently
   Number 10 fruit and vegetable cans)

   b. Various fertilizers and soil amendments.

   c. Wax pencil or lead pencil.

   d. Wooden pot labels.

   e. Measuring spoons or gram scales.

   f. Soil - seeds or transplants. Transplants should be started in spong-rok, avolite, or washed sand so they don't have large nutrient carry over.

2. Procedure:

   a. Punch 3 to 4 holes in base of each can.

   b. Fill cans approximately half full of soil. Settle soil in can by tapping bottom against solid surface.

   c. Label can with information showing:

   Fertilizer treatment

   Name - date - etc.

   d. Sprinkle proper amount of fertilizer on top of soil.

   e. Add 2 - 2½" of soil on top of fertilizer.

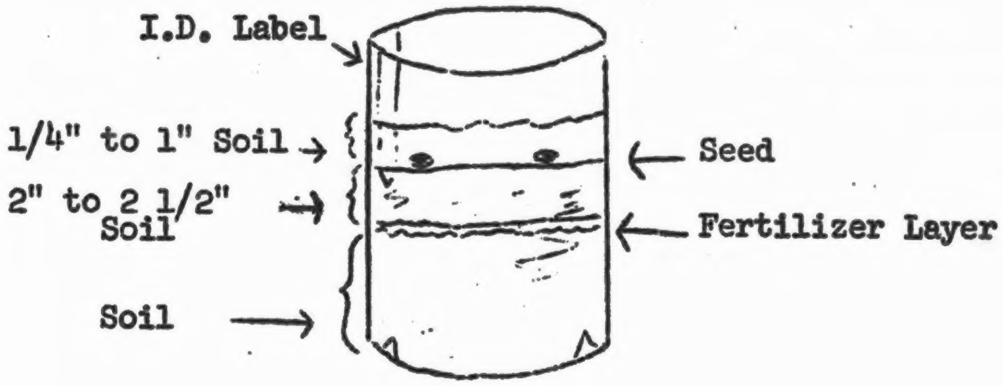
   f. Plant seed.

   g. Cover seed with ¼" to 1" of soil depending on size of seed.

   h. Moisten and keep moist for entire growing period. Do not over-irrigate and leach nutrients from can.

   i. Make periodic observations and write up comparative reports and conclusions.

j. Leave one can with no fertilizer treatment to serve as a check.



3. Quantities of various fertilizers and amendments required to supply a given application rate per acre. The amounts shown are for TWO lbs. of soil. Vary the amount used according to the amount of soil used in your cans.

Rate Teaspoon	Grams	Fertilizer	Approx. Equivalent in Pounds Per Acre
1/8	.13	Ammonium Nitrate	60# of nitrogen
1/4	.26	Ammonium Nitrate	120# of nitrogen
1/2	.52	Ammonium Nitrate	240# of nitrogen
1/8	.19	Ammonium Sulfate	60# of nitrogen 70# of sulfur
1/4	.38	Ammonium Sulfate	120# of nitrogen 140# of sulfur
1/2	.76	Ammonium Sulfate	240# of nitrogen 280# of sulfur
1/20	.08	Treble Super Phos.	60# of phosphate
1/10	.16	Treble Super Phos.	120# of phosphate
1/5	.32	Treble Super Phos.	240# of phosphate
1/8	.13	Ammonium Nitrate	60# of nitrogen
1/20	.08	Treble Super Phos.	60# of phosphate
1/4	.26	Ammonium Nitrate	120# of nitrogen
1/10	.16	Treble Super Phos.	120# of phosphate

Rate Teaspoon	Grams	Fertilizer	Approx. Equivalent in Pounds Per Acre
1/2	.52	Ammonium Nitrate	240# of nitrogen
1/5	.32	Treble Super Phos.	240# of phosphate
1/4	.9	Gypsum	1000#/Ac
1/2	1.8	Gypsum	2000#/Ac
1/4	.9	Lime or dolomite	1000#/Ac
1/2	1.8	Lime or dolomite	2000#/Ac
1/5	.45	Soil Sulphur	500#/Ac
2/5	.9	Soil Sulphur	1000#/Ac

REFERENCES AND INSTRUCTIONAL MATERIALS

Textbooks:

1. Tisdale, S. L. and Nelson, W. L., Soil Fertility and Fertilizers. New York: The Macmillan Co.

2. The Fertilizer Handbook. National Plant Food Institute, 1700 K Street, N.W., Washington, D.C.

3. Western Fertilizer Handbook, California Fertilizer Association, 719 K Street, Sacramento, California.

4. McVickar, M. H., Using Commercial Fertilizers, Danville, Illinois, Interstate Printers and Publishers.

5. Dictionary of Plant Foods. Published by Farm Chemicals. Available through the Nitrogen Division, Allied Chemical and Dye Corporation, Hopewell, Virginia.

6. Black, C. A., Soil - Plant Relationships, New York: John Wiley and Sons, Inc.

7. Hunger Signs in Crops. American Society of Agronomy and The National Fertilizer Association, Washington, D.C.

8. Bear, Firman E., Soils and Fertilizers, New York: John Wiley and Sons, Inc.

9. Spurway, C. H., Soil Fertility Diagnosis and Control. Published by the author, East Lansing, Michigan.

10. 1957 Yearbook of Agriculture Soil, U.S.D.A., Washington, D.C. Available through U. S. Government Printing Office.

11. Diagnosis and Improvement of Saline and Alkali Soils, Agriculture Handbook No. 60, U.S.D.A. Available through the U. S. Government Printing Office.

12. Buckman, Harry O and Brady, Nyle C., The Nature and Properties of Soils, New York: The Macmillan Co.

13. Donahue, Roy P., Soils, Englewood Cliffs, New Jersey. Prentice-Hall, Inc.

Government Bulletins and Special Publications:

1. McGhee, Claude, Plant Nutrition, Morgantown, West Virginia; West Virginia University, 1964.

2. Walsh, Beatty, Hull and Wiese, Lime and Fertilizer Recommendations for Field Crops, Madison, Wisconsin; University of Wisconsin, 1962.

3. Soils and Fertilizers 1965 Guide for Fertilizer Dealers, Cooperative Extension Service and Agronomy Department, So. Dakota State University, Brookings, So. Dakota.

4. Soil Fertility and Fertilizer for Ohio Farms, Bulletin 395, Cooperative Extension Service, The Ohio State University, Columbus, Ohio. Reprinted 1965.

5. Miller, Harold F., Know Your Fertilizer. Miscellaneous Bulletin 209, Cooperative Extension Service, University of Kentucky.

6. Walsh, L. M., Beatty, M. T. et al., Profitable Management of Wisconsin Soils, Madison, Wisconsin; College Printing and Typing Co., 1963.

7. Wiese, R. A., and Walsh, L. M., Soil Samplers Manual, Madison, Wisconsin, University of Wisconsin, 1964.

8. Walsh, Leo M., Fertilizer Demonstrations on Corn, Small Grain, Hay and Pasture, Madison, Wisconsin, University of Wisconsin, 1961.

9. Plant Response to Fertilizers on a Saline Soil, Agriculture Exp. Station, New Mexico State University, 1964.

10. How to Sample Soils for Testing, Bulletin 388, The Ohio State University, Columbus, Ohio.

11. Salt Tolerance of Plants, Bulletin 283, U.S.D.A.

12. Plant Testing, American Potash Institute, 1102 16th Street, N.W., Washington, D.C., 1962.

13. Fight Hidden Hunger with Chemistry, American Potash Institute, 1964.

14. Plant Analysis and Analytical Methods, Bulletin 766, California Agriculture Exp. Station, University of California, Davis, California, 1959.

15. How to Evaluate Agricultural Liming Materials, M. M. - 198, Cooperative Extension Service, The Ohio State University, Columbus, Ohio.

16. Musgrave, O. L., How to Use Your Soil Test Results, Leaflet 194, Cooperative Extension Service, The Ohio State University.

17. Fertilizer Facts, Industrial and Biochemicals Department, E. I. duPont de Nemours and Co., Wilmington 98, Delaware.

18. Sunset Magazine, "Lawns and Ground Covers"; published by Lane Book Co., Menlo Park, California.

19. Sunset Magazine, "Basic Gardening Illustrated"; published by Lane Book Co., Menlo Park, California.

SUGGESTIONS

a. Write your State Agricultural Experiment Station for a list of publications and films dealing with soils and fertilizers.

b. Write the American Potash Institute, 1102 16th Street, N.W., Washington, D.C., for a complete list of publications and films they have available.

c. Many commercial fertilizer firms have publications and films. Contact the local dealer for information.

THE CENTER FOR RESEARCH AND LEADERSHIP DEVELOPMENT
IN VOCATIONAL AND TECHNICAL EDUCATION
THE OHIO STATE UNIVERSITY
980 KINNEAR ROAD
COLUMBUS, OHIO, 43212

INSTRUCTOR NOTE: As soon as you have completed teaching each module, please record your reaction on this form and return to the above address.

1. Instructor's Name____

2. Name of school________________________State______________

3. Course outline used:
   _____Agriculture Supply--Sales and Service Occupations
   _____Ornamental Horticulture--Service Occupations
   _____Agricultural Machinery--Service Occupations

4. Name of module evaluated in this report________________________

5. To what group (age and/or class description) was this material presented?____
____

6. How many students:
   a) Were enrolled in class (total) ________
   b) Participated in studying this module ________
   c) Participated in a related occupational work experience program while you taught this module ________

7. Actual time spent teaching module:

Actual time spent teaching module:		Recommended time if you were to teach the module again:
_____hours	Classroom Instruction	_____hours
_____hours	Laboratory Experience	_____hours
_____hours	Occupational Experience (Average time for each student participating)	_____hours
_____hours	Total time	_____hours

(RESPOND TO THE FOLLOWING STATEMENTS WITH A CHECK (✓) ALONG THE LINE TO INDICATE YOUR BEST ESTIMATE.)

	VERY APPROPRIATE — NOT APPROPRIATE
8. The suggested time allotments given with this module were:	|____.____.____.____.____|
9. The suggestions for introducing this module were:	|____.____.____.____.____|
10. The suggested competencies to be developed were:	|____.____.____.____.____|
11. For your particular class situation, the level of subject matter content was:	|____.____.____.____.____|
12. The Suggested Teaching-Learning Activities were:	|____.____.____.____.____|
13. The Suggested Instructional Materials and References were:	|____.____.____.____.____|
14. The Suggested Occupational Experiences were:	|____.____.____.____.____|

(OVER)

15. Was the subject matter content sufficiently detailed to enable you to develop the desired degree of competency in the student? Yes_____No_____
Comments:

16. Was the subject matter content directly related to the type of occupational experience the student received? Yes_____No_____
Comments:

17. List any subject matter items which should be added or deleted:

18. List any additional instructional materials and references which you used or think appropriate:

19. List any additional Teaching-Learning Activities which you feel were particularly successful:

20. List any additional Occupational Work Experiences you used or feel appropriate:

21. What do you see as the major strength of this module?

22. What do you see as the major weakness of this module?

23. Other comments concerning this module:

______________________________ (Date)

______________________________ (Instructor's Signature)

______________________________ (School Address)